IBEXIAN - WHITEROCKIAN (ORDOVICIAN) CONODONT PALAEONTOLOGY OF EAST AND EASTERN NORTH GREENLAND

by

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I dedicate this work to my grandfather, the late Jack Hannan, who inspired and encouraged me from an early age.

The high hills are a refuge for the wild goats:
and so are the stony rocks for the conies.

Psalm 104.18

The Book of Common Prayer, 1662

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ABSTRACT

Samples collected from mid-Ibexian (mid-Tremadoc) to late Whiterockian (Llandeilo) of East and eastern North Greenland have yielded a total of 9,725 identifiable conodont elements. The conodonts are referred to 54 multi-element genera and 115 species, new taxa include three genera (*Macheticodus*, *Wandelia* and *Weberina*) and nine species (*Eucharodus apion*, *Macheticodus lekiskus*, *Multioistodus? celox*, *Pteracontiodus armillatus*, *Scalpellodus? narvhalensis*, *Sibiriodus? kalalekus*, *Wandelia fuscina*, *Weberina candidisphaera* and *Weberina guyi*). The faunas are coniform-dominated and generally similar to shallow water, Midcontinent Province faunas found in North America. Some degree of endemicity is indicated by the presence of species found only in the eastern Canadian Arctic Islands and Greenland.

The conodonts are referred to ten biozones, of which three zones in the Ibexian are newly named (the *Loxodus bransoni*, *Glyptoconus quadraplicatus* and *Oepikodus communis* Zones) as are three Ibexian sub-zones (the *Acodus deltatus*, *?Reutterodus andinus* and *Protoprioniodus aranda*). These are all based on the previous, informal faunal divisions established in North America.

In East Greenland, the oldest faunas recovered, from the base of the Cape Weber Formation on Ella Ø, are referred to the *L.bransoni* Zone (mid-Ibexian). Both upper and lower boundaries are, however, diachronous and on Albert Heim Bjerge, 150km to the north, the base of the formation contains conodonts of the younger *G.quadraplicatus* Zone. On Ella Ø, the Ibexian-Whiterockian boundary occurs within the lower part of the Narwhale Sound Formation and the youngest conodonts recovered are

referable to the *Histiodella altifrons* Zone (early Whiterockian). The youngest Ordovician conodonts recovered from East Greenland are from the Heim Bjerge Formation, directly underlying Devonian conglomerates, on C.H.Ostenfeld Nunatak; these faunas contain taxa of the *Polyplacognathus sweeti* Zone (late Whiterockian).

In eastern North Greenland, the Wandel Valley Formation unconformably overlies Cambrian carbonates, and conodonts recovered from the base probably belong to the *O.communis* Zone (late Ibexian). The Ibexian-Whiterockian boundary lies at or just above the lower boundary of the Upper Member and the top of the formation contains taxa referable to the *Polyplacognathus friendsvillensis* Zone (late Whiterockian).

Contouring of the colour alteration indices (CAI) in North Greenland indicates that the isotherms are parallel to the margin of the Hazen Trough; to the east, in Kronprins Christian Land, they swing around to become parallel to the Caledonian front.

Fused clusters recovered from the Cape Weber and Heim Bjerge Formations are amongst the oldest euconodont assemblages recorded. They are principally of coniform species and suggest a grasping function analogous to that of chaetognath spines.

ACKNOWLEDGEMENTS

My thanks are due foremost to Dr. R.J. Aldridge for his fine supervision, patience and readiness to discuss all aspects of this work. I am also greatly indebted to Dr. J.S. Peel (GGU) for advice, help and encouragement throughout the project and wish to give especial thanks to the efforts of Dr J.E. Mabillard, Mr. P. Frykman, Dr J.S. Peel and Mr J.R. Ineson who collected the samples and without whom this project would not have been possible.

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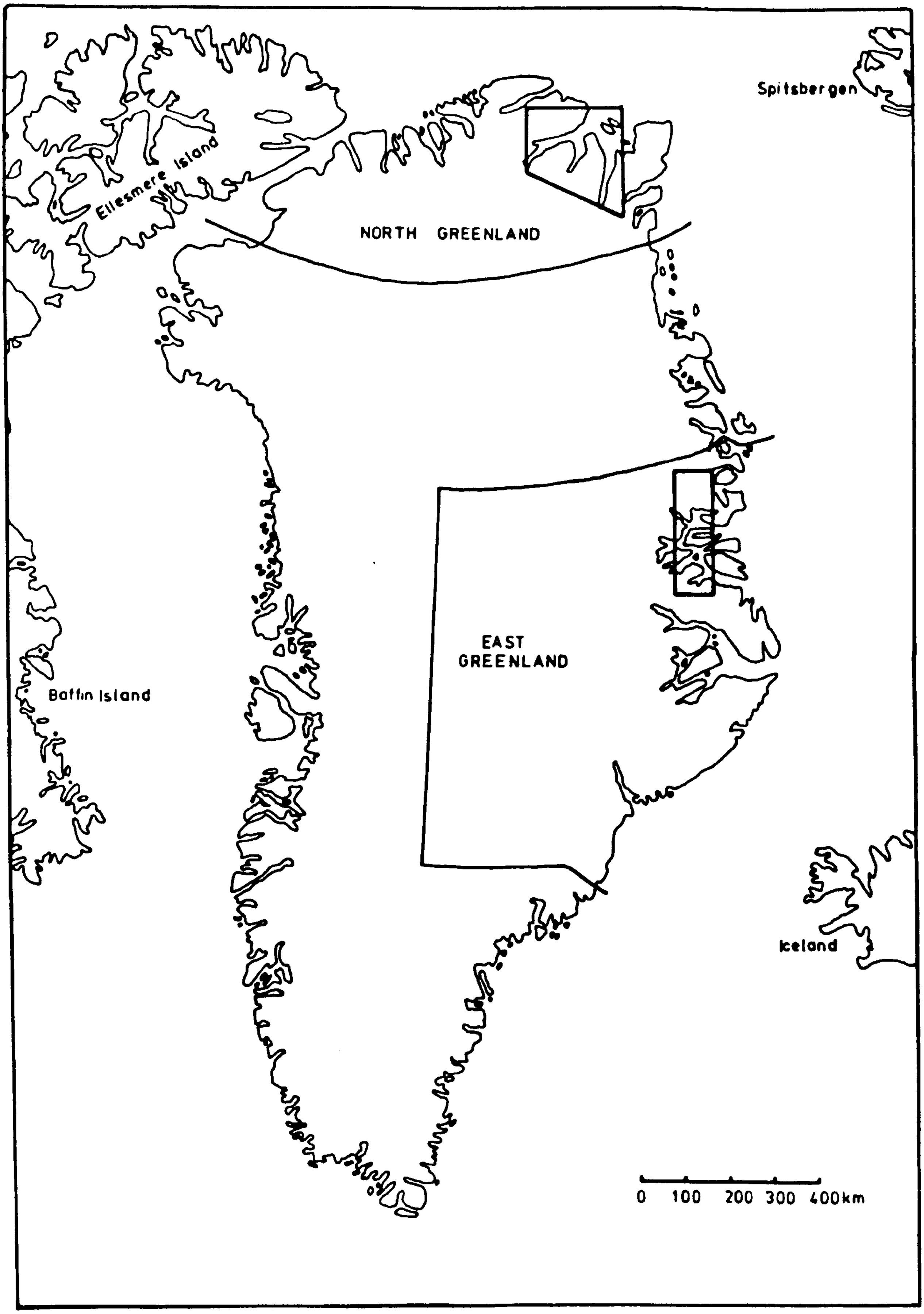
I would like to express my gratitude to all colleagues and co-workers who have given their time for discussion; especially Dr J.E. Mabillard, for initiating me into conodont work, Dr I.D. Bryant, for playing the devil's advocate on every possible occasion, and to Dr H.A. Armstrong for many invigorating discussions on apparatus structure and nomenclature and for his unique way of telling me I was mistaken.



Geographical divisions of Greenland, showing principal study areas

CHAPTER 1

INTRODUCTION

1.1. PHYSIOGRAPHY

The east coast of Greenland consists of an ice-free belt of land, mostly about 100 km wide and of a mountainous nature. The Inland Ice impinges on the west of this belt and splits into large, valley glaciers, deeply dissecting the mountains and affording excellent profiles through the Caledonian fold belt. This is particularly true of the area involved in this study (71° - 73° N) where exposure is further enhanced by the unusually wide area of ice-free land, up to 300 km.

The eastern part of North Greenland consists of two physiographic units; a mountainous belt in north Peary Land and Nansen Land and a low-lying plateau in south Peary Land and surrounding areas. The ice-free area is 250 km from the coast to the Inland Ice at the widest point. The western limit of this study is Hans Tavsens Iskappe, an ice cap detached from the main body of the Inland Ice.

1.2. HISTORY OF EXPLORATION

The first description of East Greenland geology was made in 1823 by William Scoresby. Together with Jameson, who described the rocks collected, he concluded that a great proportion of the east coast was composed of "primitive" rocks. A long gap ensued before the German North Pole expedition of 1869 - 70 led by J. Payer made observations of the geology from 73° - 76° N. In addition to studies on the Mesozoic and Caenozoic, von Hochstetter et al. (1874) referred sediments directly overlying the crystalline rocks to the Hecla Hook Formation defined on Spitsbergen. In 1891, a Danish Navy expedition entered Scoresby Sund and Bay (1896) described the Mesozoic plant beds seen in Jameson Land.

A major contribution to the understanding of East Greenland geology came on the 1899 Swedish expedition. Nathorst explored the inner parts of Keiser Franz Joseph Fjord and realised that the "Hecla Hook Formation" could be divided into "Silurian" and Devonian (Nathorst, 1901). He noticed that the Silurian was metamorphosed, folded and overlying what he considered to be Archaean basement but also noted that the folding was pre-Devonian, Nathorst was thus the first person to recognise the East Greenland fold belt as Caledonian in age. Nordenskjöld (1907) came to much the same conclusion on Amdrup's Danish Navy expedition of 1900.

The first description of North Greenland geology came in 1892 when Peary traversed from western North Greenland to the east coast. He reached Independence Fjord and there described widespread, ripple-marked, red sandstones. To the north, the expedition sighted the ice-free, mountainous area of Peary Land, separated from the mainland by the Peary Channel. In 1906, the Danmark expedition set out to explore eastern North Greenland and the Peary Channel. The leader, Mylius-Erichsen and colleagues mapped Danmark Fjord and parts of Independence Fjord but all died on the return journey. On the same expedition, J.P. Koch and Alfred Wegener collected Upper Palaeozoic sediments at 80° N.

Ejnor Mikkelsen set out to search for the previous expedition in 1910. The bodies were found, and maps found with them confirmed that the Peary Channel did not exist and that Hagen and Jorgen Brønlund Fjords had been discovered. After a few years, J.P. Koch and Wegener returned to North Greenland and traversed from the east to the west coast, noting that sediments reappear to the west of Dronning Louise Land (77° N).

A new period of geological research opened in 1912 with the first Thule expedition led by K. Rasmussen. The expedition travelled from Thule to Danmark Fjord and observations en route resulted in the publication of "Geology of Greenland" (Bøggild, 1917). North Greenland was divided into two elements, a northern mountainous region and a southern sediment plateau of Cambrian or Devonian age.

The second Thule expedition (1916 - 18) traversed the north coast, the main geological objective being to determine the age of the fold belt. Lauge Koch, the expedition geologist, determined from graptolite evidence that the earliest possible age was late Silurian.

Koch returned in 1920 - 23, on the Danish Bicentenary Expedition and fossils collected on this expedition were described by Poulsen (1927, 1934, 1941, 1943, 1958) and Troedsson (1926, 1929). In his "Geology of North Greenland" (1925), Koch divided North Greenland into an Archaeozoic gneiss plain, a sediment plain and a Caledonian folded zone.

A third period of exploration opened in 1926 when Cambridge University and Koch both undertook East Greenland expeditions. This was the first of a series of expeditions led by Koch which lasted until 1958 with breaks only for the war years. The end result was the publication of the 1:250,000 geological map (Koch and Haller, 1971) and the 1:500,000 tectonic map of East Greenland (Haller, 1970). Extensive work was also carried out in eastern North Greenland and it was during this period that Cowie and Adams (1957) undertook the detailed description of the Cambro-Ordovician of East Greenland.

Little further work was done until the late 1960's. Jepsen, as part of the 4th and 5th Danish Peary Land Expeditions (1966 - 68) mapped the sediments of southern Peary Land and established the basic stratigraphic scheme still used by Grønlands Geologiske Undersøgelse (GGU). Appraisal of potential oil resources was carried out by the Greenarctic Consortium from 1967 - 73 although little of this research has been published.

The most recent research has been as part of GGU mapping programmes. Systematic mapping of the east coast from 70° - 72° N was carried out between 1968 and 1972 with reconnaissance mapping of 72° - 74° N between 1975 and 1978. The East Greenland samples studied in this thesis were obtained as part of the latter programme.

Field work was undertaken in Washington Land from 1975 to 1978 with the aim of establishing stratigraphic profiles and correlating them with sections across all of North Greenland and, eventually, making a map. A systematic mapping programme was started in North Greenland in 1978 with the last field season scheduled for 1985. The material from North Greenland studied herein forms a part of this programme.

1.3. PREVIOUS LOWER PALAEOZOIC MICROPALAEONTOLOGICAL RESEARCH IN GREENLAND

There are few systematic studies of Lower Palaeozoic conodont faunas from Greenland. Stouge and Peel (1979) described a late Middle Ordovician to Upper Ordovician collection from a fault-zone breccia in the Precambrian Shield of West Greenland. The only other fully published Ordovician work is the description of *Besselodus arcticus* from a fused cluster recovered from the Aleqatsiaq Fjord Formation of Washington Land (Aldridge, 1982).

Further Ordovician conodont work is, as yet, only in abstract or short communication form. Miller and Kurtz (1979) reassigned the Dolomite Point Formation of East Greenland to the Ordovician on the basis of conodont evidence and preliminary age determinations of the East Greenland carbonate sequence have been published by Stouge (1978), Kurtz and Miller (1981) and Smith (1982). Stouge (1977) has also listed conodonts recovered from the Cape Clay Formation of Washington Land.

Silurian conodonts have been described from the upper part of the un-named Silurian Limestone Formation of Peary Land by Aldridge (1979) whose conodont data was also incorporated in the stratigraphic scheme for Washington Land by Hurst (1980a). A detailed study of conodonts from Silurian sequences right across North Greenland has been made by Armstrong (1983) in an unpublished PhD thesis.

An even smaller amount of research has been completed on other microfossil groups. Lane (1980) described *Monoceratella mazos* a new species of ostracod, from the Silurian of Washington Land. Chitinous hydroids have been described by Frykman (1979a) from the Ordovician Børglum River Formation of Peary Land and Aldridge & Armstrong (1981) discovered a new group of spherical, spinose phosphatic microfossils, mazuelloids, from the Silurian of Peary Land.

The enigmatic, phosphatic spine *Anatolepis*, previously attributed to early fish (Bockelie and Fortey, 1976; Repetski, 1978), was postulated to be an arthropod telson by Peel and Higgins (1977) and Peel (1979) on the basis of material recovered from the Lower Ordovician Cape Weber Formation of East Greenland.

1.4. TECHNIQUES

1.4.1. Collection

The samples in this study were collected between 1977 and 1980 by geologists on GGU expeditions, principally J.S. Peel, P. Frykman, J.E. Mabillard and J.R. Ineson. The samples were collected at 10 - 20 m intervals and varied in size from 500 - 4300 g. The majority of samples from North Greenland were between 1500 and 2500 g and the majority of those from East Greenland 1000 - 1500 g.

1.4.2. Preparation

In the laboratory, limestone samples were broken into fist-sized pieces and dolomites crushed to 10 - 20 mm pieces before being dissolved in 10% acetic acid. This strength of acid will attack phosphate unless sufficient Ca^{2+} ions are present to buffer the solution (L. Jeppsson, pers. comm.). Therefore, powdered calcium carbonate was added to dolomite samples prior to immersion in acid.

At the end of one week, samples were washed through 1 mm and 75 sieves. Residues on the latter were retained and those on the former returned to acid. After maximum breakdown (2 - 3 weeks) the samples were separated in bromoform ($CHBr_3$. S.G. 2.89).

Problems were encountered when separating dolomite residues in new bromoform. Manufacturers commonly add 1% alcohol as a stabiliser and this reduces the specific gravity to 2.65 (Allman and Lawrence, 1972, Fig. 116) allowing the dolomite to sink. All bromoform was therefore washed with water, prior to use for the first time, in order to remove the alcohol.

Heavy residues were picked completely into four-holed slides and light residues scanned for other microfossils.

1.4.3. Storage and Illustration

During identification, samples were transferred to 25 or 100 square slides backed with photographic paper and labelled with the GGU sample number and formation abbreviation. Copies of lithological descriptions, a hand specimen and processing details are stored at the Department of Geology, University of Nottingham.

Specimens were photographed on an ISI SX-30 scanning electron microscope using Ilford FP4 35 mm film. Repetski and Brown (1982) considered the most practical way to coat specimens for scanning electron microscopy was with a very thin layer of carbon, thus leaving specimens transparent. Aluminium coating was used in this study and has the advantage of being a better conductor and easily removed with 5% NaOH (as opposed to plasma ashing to remove carbon). Photographs were printed on Kodak F1 and F2 photographic paper.

All line drawings and conodont alteration index determinations were made on a Nikon SMZ-10 binocular microscope with camera lucida attachment.

CHAPTER 2

REGIONAL GEOLOGY

The Lower Palaeozoic rocks of Greenland occur in two provinces. One, the Innuitian Province, extends westwards from Peary Land across North Greenland, Ellesmere Island and Devon Island and terminates on Melville Island (Fig. 2.1). This province shows two phases of development separated by the Devonian-Carboniferous Ellesmerian Orogeny.

The second province is the East Greenland Fold Belt, an orogenic belt of Precambrian and Lower Palaeozoic rocks deformed during the Caledonian orogeny. A thick succession of Upper Palaeozoic to Tertiary rocks overlies the fold belt.

The relationship between the Innuitian Province and the Caledonian Fold Belt is crucial to the understanding of the plate tectonic history of the Arctic region. Unfortunately, the intersection is concealed beneath the Wandel Hav, which is the site of a late Palaeozoic to Tertiary sedimentary basin.

2.1. THE INNUITIAN PROVINCE

Comprehensive overviews of the geological history of the Canadian part of the province have been provided by Thorsteinsson and Tozer (1970) and Trettin and Balkwill (1979). The regional geology of North Greenland has been described by Dawes (1976), Dawes and Peel (1981) and Surlyk and Hurst (1983). The terminology of Trettin and Balkwill (1979) will be used for both areas of the Innuitian Province since it

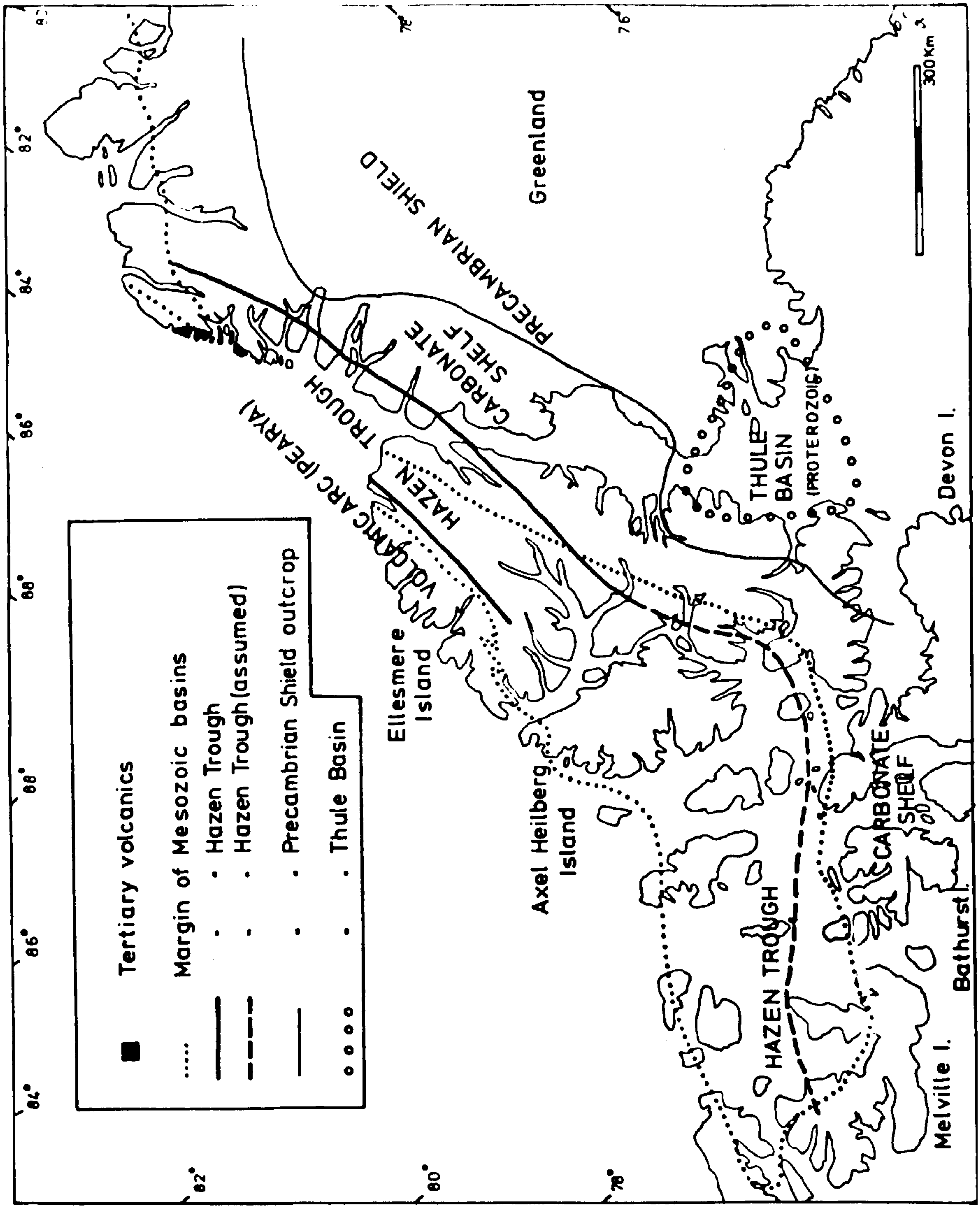


Fig. 2.1 Geology of the Innuitian Province (modified after Trettin & Balkwill, 1979, and Dawes, 1976)

is the least ambiguous. The basin as a whole, the Franklinian Basin, can be divided into three major depositional belts in the Lower Palaeozoic; the northern shelf (Pearya), the Hazen Trough and the southern shelf. The basin was considered to be ensialic by Trettin and Balkwill (1979) and either an aulacogen or a narrow ocean by Surlyk and Hurst (1983).

2.1.1. Pearya

The rocks of the northern shelf are currently only visible in northern Ellesmere Island. They consist of volcanics, shallow marine, carbonate sediments and shallow marine to non-marine clastic sediments. The volcanic rocks are of felsic to intermediate composition (Trettin and Balkwill, 1979). The northern shelf is not seen in Greenland, since its presumed site lies under the present Arctic Ocean. There is, however, evidence to show that it acted as a major source of sediment and as a control on sedimentation (Surlyk *et al.*, 1980; Surlyk and Hurst, 1983).

2.1.2. Hazen Trough

The trough area of the Franklinian Basin is represented in North Greenland by rocks outcropping in northern Peary Land and Johannes V. Jensen Land (Fig. 2.1.). Two facies types are present throughout the Province; turbidites derived from the shelf margins and a starved basin facies consisting of cherts and mudstones (Friderichsen *et al.*, 1982; Surlyk *et al.*, 1980). Turbidite deposition in the late Proterozoic and Cambrian gave way to the starved basin facies in the latest Cambrian but recommenced in the latest Ordovician and continued through the Silurian (Surlyk and Hurst, 1983). In the late Llandovery, a large area of the platform east of Victoria Fjord foundered and trough sediments then succeed the carbonates in this area (Surlyk et al., 1980). The youngest basinal sediments in North Greenland are dated by graptolites to be of "Pridoli" age (op. cit.).

The structure of the northern margin of the trough is poorly known, but shelf/trough alternations may indicate that it was poorly defined (Trettin and Balkwill, 1979). These authors considered the southern margin in Arctic Canada to be represented by a broad flexure but Surlyk et al. (1980) consider that in Greenland it is fault-bounded, with faults that migrated and became intra-basinal with time. Migration of the faults is considered unlikely by Higgins, Friderichsen and Soper (1981).

2.1.3. Southern Shelf

During the Proterozoic, two main basins were actively subsiding in North Greenland. The Thule Basin, with 4,500 m of sediment, is connected to the Peary Land - Kronprins Christian Land Basin by only very thin, mainly clastic, sediments (Dawes and Peel, 1981). The sediments of the latter basin are referred to the Independence Fjord Group and consist of at least 1,750 m of thick, homogeneous red sandstones with thin siltstones (Collinson, 1980). South of Independence Fjord, the group is overlain by up to 1,350 m of tholeitic basalt, the Zig Zag Dal Basalt Formation (Jepsen et al., 1980). Several hundreds of metres of Proterozoic clastics and dolomites overlie the Independence Fjord Group and Zig Zag Dal Basalt Formation. The earliest Cambrian rocks seen are stromatolitic dolomites of the Portfjeld Formation, found only in eastern North Greenland. The overlying sandstones and shales of the Buen Formation can however be correlated with other Lower Cambrian formations in western North Greenland and Canada although most of the Cambrian in Peary Land bears little resemblance to these other sequences (Peel and Christie, 1982). In all areas except Peary Land the Cambrian succession is complete but a major unconformity occurs below the Lower Ordovician in Peary Land. The carbonates and sandstones of the Brønlund Fjord Group and Tavsens Iskappe Group are 900 m thick around Hans Tavsens Iskappe but are overstepped at progressively lower levels to the east (Fig. 3.1.) (Ineson and Peel, 1980; Peel, in press).

The Ordovician is discussed in more detail in Chapter 3 but consists of limestones, dolomitic limestones and dolomites which can be correlated across the southern shelf of the Innuitian Province. One of the few variations is an increasing uniformity to the east, resulting in fewer formations and fewer evaporite beds (Peel and Christie, 1982).

The Silurian deposited on the shelf prior to foundering are also carbonate dominated. In Peary Land, the basal 150 m is of dolomite and the remaining 320 m consists of pale grey and dark grey micrites (Christie and Peel, 1977). The Washington Land sequence comprises two broad environments, platform and basin slope. The platform is mainly represented by micrites with skeletal limestones and the basin slope by mudstones, cherts and resedimented conglomerates (Hurst, 1980a). The junction between the two is complex and often marked by the occurrence of reefs (Hurst, 1980b).

2.1.4. Ellesmerian Orogeny

The Ellesmerian Orogeny caused the most extensive deformation of rocks in the Innuitian Province although the Greenland section of the fold belt is still not well understood. Dawes (1976) was, however, able to divide the fold belt into tectono-metamorphic zones (Fig. 2.2.). Fold styles vary from north to south but the folds are all co-axial and trend E-W. In the south, the folding is open, passing into large scale, south-trending structures on the trough margin (Dawes, 1976; Pedersen, 1979). These grade northwards into upright folds and in the far north the structures become overturned. There is also a progressive increase in metamorphic grade from unmetamorphosed in the south, through chlorite grade, to biotite grade and eventually amphibolite facies in the extreme north (Dawes and Soper, 1973).

The onset of orogenesis has a maximum age of Lower Devonian, since Pridolian graptolites are found in marginal areas of the fold belt (Hurst _et al._, 1980). The youngest overlying sediments are late Carboniferous but the same basin does contain Dinantian strata to the south (Håkansson et al., 1981). Thus the main orogeny can be placed between the early Devonian and early Carboniferous. This compares closely with stratigraphic constraints in Arctic Canada (Trettin and Balkwill, 1979).

2.1.5. Post-Orogenic History

During the early Carboniferous, a sedimentary basin developed at either end of the Innuitian Province. In Arctic Canada, the Sverdrup Basin received sediment until the late Cretaceous (Trettin

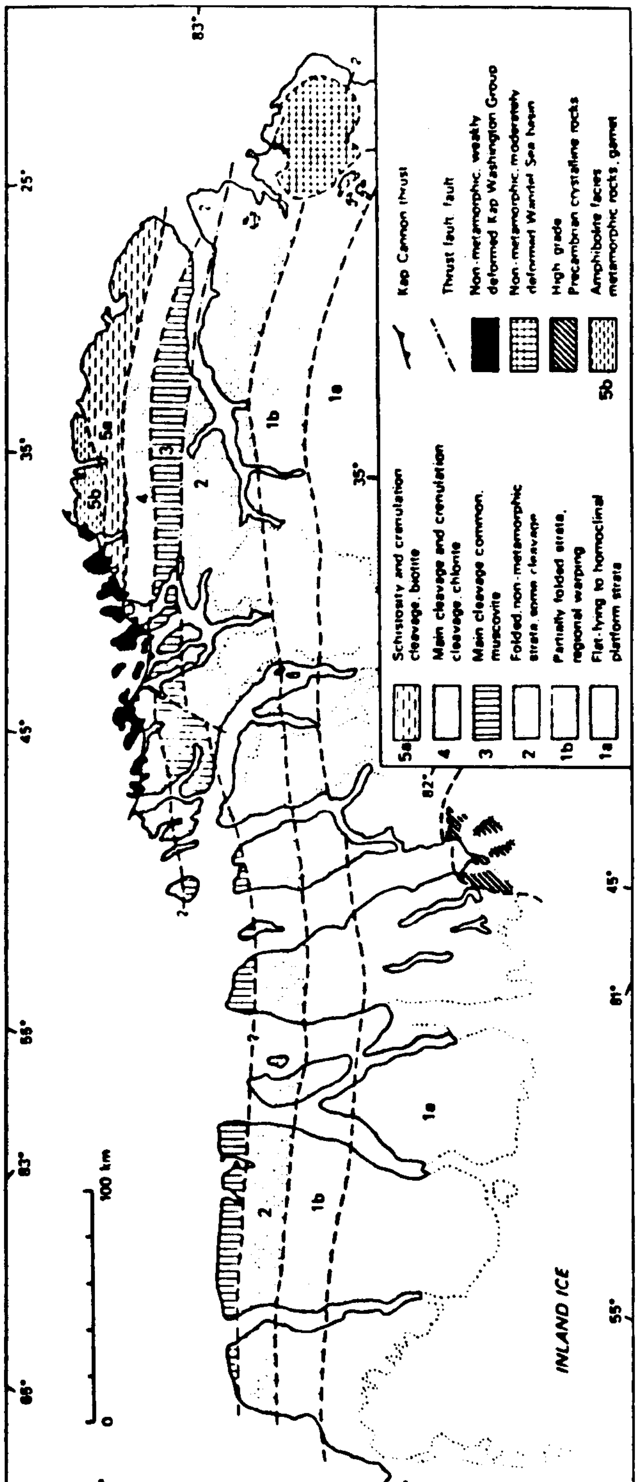


Fig. 2.2 Tectono-metamorphic units of the North Greenland fold-belt and platform (from Dawes, 1976)

and Balkwill, 1979) and in eastern North Greenland the Wandel Sea Basin accumulated up to 7 km of sediment.

Igneous activity is indicated in the late Cretaceous by the presence of calc-alkaline volcanics at Kap Washington in extreme North Greenland (Brown and Parsons, 1981). These rocks are subsequently affected by mid-Tertiary thrusting, mylonitisation and greenschist metamorphism and are likely to be onshore reflections of the opening of the Arctic Ocean (Higgins et al., 1981). The volcanics were attributed by Brown and Parsons (1981) to crustal thinning and extension prior to this opening.

2.2. THE CALEDONIAN FOLD BELT OF EAST GREENLAND

The geology of the area has been reviewed by Haller (1971) and Henriksen and Higgins (1976). A 1:250,000 geological map of the area has been published (Koch and Haller, 1971) as has a 1:500,000 tectonic map (Haller, 1970).

In the area between 72° and 74° N the orogen can be divided into two groups; metamorphic crystalline complexes and Proterozoic to Lower Palaeozoic sediments.

2.2.1. Metamorphic Crystalline Complexes

The earliest workers considered the gneiss complexes in the Keiser Franz Joseph's Fjord area to be of Archaean age and basement character (Nordenskjöld, 1907; Wordie, 1930). Later workers (Wegmann, 1935; Haller, 1971) put forward the "stockwerke" model which envisages highly mobile fronts of migmatisation involving both basement and sediment upwelling to form domes, mushrooms and "nappes". One consequence of the theory is that the crystalline complexes must be regarded as younger than the surrounding sediments.

Recent isotopic studies (Steiger et al., 1979; Rex and Gledhill, 1981) have shown that the crystalline complexes are not of Caledonian age, as the stockwerke model predicts, but of Archaean and Proterozoic age. Higgins, Friderichsen and Thyrsted (1981) conclude that the essential petrological and structural character of the infracrustal complexes is largely a reflection of pre-Caledonian events although appreciable metamorphism and deformation was imposed during the Caledonian orogeny.

2.2.2. Late Proterozoic and Lower Palaeozoic Sediments

The late Proterozoic Eleonore Bay Group outcrops in two belts, an outer fjord belt and an inner belt in the fjord region. The two areas are separated by the Central Metamorphic Complex (Fig. 2.3.). The Lower Eleonore Bay Group is at least 9350 m thick and clastic-dominated (Henriksen and Higgins, 1976). The environment has been interpreted as a subsiding, fluctuating deltaic zone (Caby, 1976). The Upper Eleonore Bay Group becomes more carbonate-dominated and the upper parts have been interpreted as shallow marine, with algal structures indicating sub-tidal depth (Caby, 1976). Acritarchs from the uppermost part of the Upper Eleonore Bay Group indicate a late Riphean age (Vidal, 1976).

The overlying Tillite Group shows a tripartite division into the tillites proper (200 - 600 m) at the base, the overlying Canyon Formation (250 - 300 m) with black shales and carbonates and the Spiral Creek Formation (25 - 55 m) with gypsiferous breccias, red mudstones and halite pseudomorphs (Henriksen and Higgins, 1976). Acritarchs indicate a Vendian age for the Tillite Group (Vidal, 1976) and there are marked hiatuses at the base and top.

The Cambro-Ordovician outcrops from 71° 36' - 72° 22' N. The Lower Cambrian is marked by a transgression and the deposition of sandstones and quartzites of the Kløftelv Formation (70 m) and glauconitic shales and sandstones of the Bastion Formation (50 m). The clastic influence wanes towards the top of the Lower Cambrian with the deposition of the sandy limestone and shales of the Ella Ø Formation (80 - 100 m). The remainder of the succession consists of dolomites and micritic limestones attaining a thickness of up to 3,700 m and is discussed in more detail in Chapter 3.

2.2.3. The Caledonian Orogeny and Post-Orogenic Development

Haller (1971) distinguished three episodes of deformation. The "Caledonian orogeny" was succeeded by "late Caledonian spasms" in the Devonian and, finally, in the late Carboniferous to Permian, " minor succeeding episodes". Since the recognition of Middle Proterozoic basement and deformation (Higgins, Friderichsen and Thyrsted, 1981) there is uncertainty as to the extent of Caledonian deformation. Only that which affects the late Proterozoic to Ordovician can be specifically attributed to this orogeny. Higgins, Friderichsen and Thyrsted (1981) considered only the broad, N-S folds in the crystalline complexes to be Caledonian.

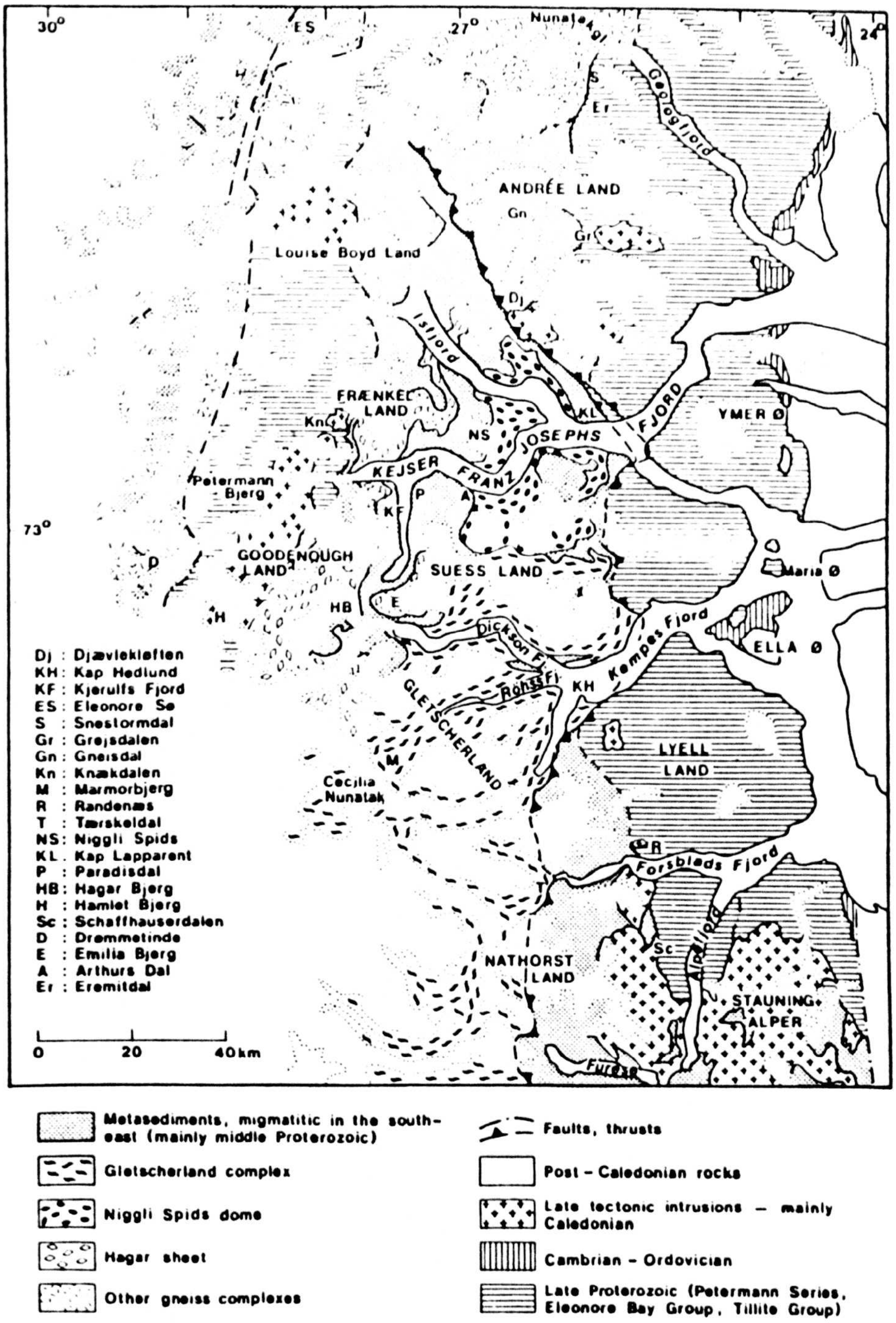


Fig. 2.3 Geological map of East Greenland (72-74^{o}N)
(from Higgins, Friderichsen & Thyrsted, 1981)

There are few constaints on the timing of orogenesis. The youngest Lower Palaeozoic strata are of early Middle Ordovician age (Smith, 1982) and vertebrates date the oldest post-orogenic rocks as early Givetian (Jarvik, 1961). Rb-Sr dating of the Caledonian granites supplies little extra data, with a range of 560 - 377 m.y. (Rex and Gledhill, 1981). If the older dates can be relied upon, the older plutons must have been intruded during the deposition of the Lower Palaeozoic platform sediments.

After the main orogenic phase, an intra-montane molasse basin was formed between 71° 30' N and 74° 30' N. The sediments are typical red, fluvial clastics with a thickness in excess of 6 km. In the northern part of the molasse basin there were four distinct episodes of intra-Devonian deformation. The first phase of molasse deposition continues into the lowermost Carboniferous and is affected by a phase of early Carboniferous deformation with N-S trending gentle folds and thrusts.

Sedimentation resumed in the Upper Carboniferous with 4 - 5 km of continental deposits accumulating up until the lower Permian. These sediments overstep all older units and constitute the last phase of molasse deposition(Haller, 1971).

2.3. RELATIONSHIP OF THE NORTH GREENLAND AND EAST GREENLAND FOLD BELTS

The junction between the Innuitian Province and the Caledonian Fold Belt lies beneath the Wandel Hav and the sediments of the Wandel Sea Basin. There are, however, a number of effects which the Caledonian orogeny has on sedimentation in the Hazen Trough and on the southern shelf.

Hurst *et al.* (1983) proposed that erosion of the rising Caledonian mountains to the east of North Greenland may have provided the sediment for the resumption of turbidite deposition in the Hazen Trough during the late Ordovician. The starved basin facies of the Amundsen Land Group (Friderichsen *et al.*, 1982) was replaced by turbidites derived from the east. These Silurian turbidites differ from earlier ones in having a significant amount of carbonate in the matrix, possibly due to derivation from nappes containing Proterozoic-Silurian carbonates (Hurst *et al.*, 1983). Such nappes are known to exist in Kronprins Christian Land.

Depression of the crust in front of the advancing nappe was invoked by Hurst *et al.* (1983) to explain the foundering of the area east of Victoria Fjord. The platform was depressed sufficiently to accommodate 2 km of turbidites above the carbonates, the collapse coinciding with reef belt formation in western North Greenland.

Structural effects of the Caledonian folding can be seen in the North Greenland fold belt. Between the Harder Fjord Fault and the southern margin of the fold belt, imbricated thrust sheets 100 - 150 m thick were displaced 1 - 10 km W or WSW prior to the E-W folding of the Ellesmerian orogeny (Pedersen, 1981). These are interpreted as gravitational mega-slides downslope into the Hazen Trough, away from the Caledonian front. This folding coincides with the time when the nappes reached their westernmost position in Kronprins Christian Land (Hurst and McKerrow, 1981; Hurst *et al.*, 1983).

The onset of the Caledonian orogeny can be correlated with the first turbiditic sedimentation in the Hazen Trough in the late Ordovician.

Cessation of the activity was, at the earliest, mid-Wenlock; since strata of this age are involved in the thrusting (Hurst and McKerrow, 1981). The oldest post-orogenic sediments in Kronprins Christian Land are earliest Carboniferous (Håkansson et al., 1981). Thus a latest Ordovician to late Silurian or Devonian range can be ascribed to the Caledonian Orogeny in Kronprins Christian Land.

CHAPTER 3

STRATIGRAPHICAL BACKGROUND

3.1. CHRONOSTRATIGRAPHY

Conodonts recovered from Ordovician strata in Greenland are of Midcontinent Province affinity (Sweet *et al.*, 1959; Bergström, 1973) and reference is hence made to American chronostratigraphical units. The Ordovician of the United States and Canada has been divided in many ways and Ross *et al.* (1982) have provided a thorough review of the historical usage of the various units. These authors also made attempts to devise a more secure chronostratigraphical scheme, with well defined unit boundaries and stratotypes, and arrived at a fourfold division of the Ordovician into series; Ibexian, Whiterockian, Mohawkian and Cincinnatian. Only the lower two series are of relevance to this work and they differ significantly from the widely used divisions of Sweet and Bergström (1976). The Ibexian Series replaces the Canadian Series, although the boundaries are the same, since the latter lacks a coherent stratotype. The Whiterockian Stage, introduced by Cooper (1956), has now been expanded to include the Chazyan Stage and elevated to Series rank. The Chazyan Stage was abandoned because it was of uncertain duration, being bounded at the base and top by unconformities.

3.2. STRATIGRAPHY OF EASTERN NORTH GREENLAND

The Ordovician succession of eastern North Greenland is divided into three formations in Peary Land and four in Kronprins Christian Land.

The base of the Ordovician sequence in these areas rests unconformably, but without angular discordance (Peel, 1982b), on Cambrian and Proterozoic sediments. There is a progressive increase in the magnitude of the unconformity from west to east (Fig. 3.1.). On the shores of Danmark Fjord, the Wandel Valley Formation rests on the Kap Holbaek Formation, a sandstone previously thought to be a lateral equivalent of the Buen Formation (L. Cambrian) but now known, on acritarch evidence, to be of late Proterozoic age (Peel, pers. comm., 1983). Around Hagen Fjord the Wandel Valley Formation rest on the Buen Formation (Peel, in press) and between Jorgen Brønlund Fjord and Hans Tavsens Iskappe the formation overlies progressively younger formations of the latest lower Middle Cambrian Brønlund Fjord Group and the Middle to Upper Cambrian Tavsens Iskappe Group (Ineson and Peel, 1980). On the west side of Tavsens Iskappe the Wandel Valley Formation rests on Formation T3 which contains *Cordylodus proavus* Zone conodonts and is hence of latest Cambrian or earliest Ordovician age (Peel, 1982a). The period of time represented by the unconformity coincides with the deposition of 375 km^3 of resedimented carbonate and chert conglomerates in the Hazen Trough of north Peary Land (Surlyk and Hurst, 1983).

3.2.1. Lithostratigraphy of Peary Land

The Wandel Valley Formation was first described by Koch (1923) in the area to the north of Wandels Dal, but was named by Troelson (1949) who noted a sharp junction with the underlying Brønlund Fjord Group. Although only the lower and middle members (of current usage) were examined by Troelson (1949), the striking difference between the pale dolomites and the overlying dark limestones of the Børglum River

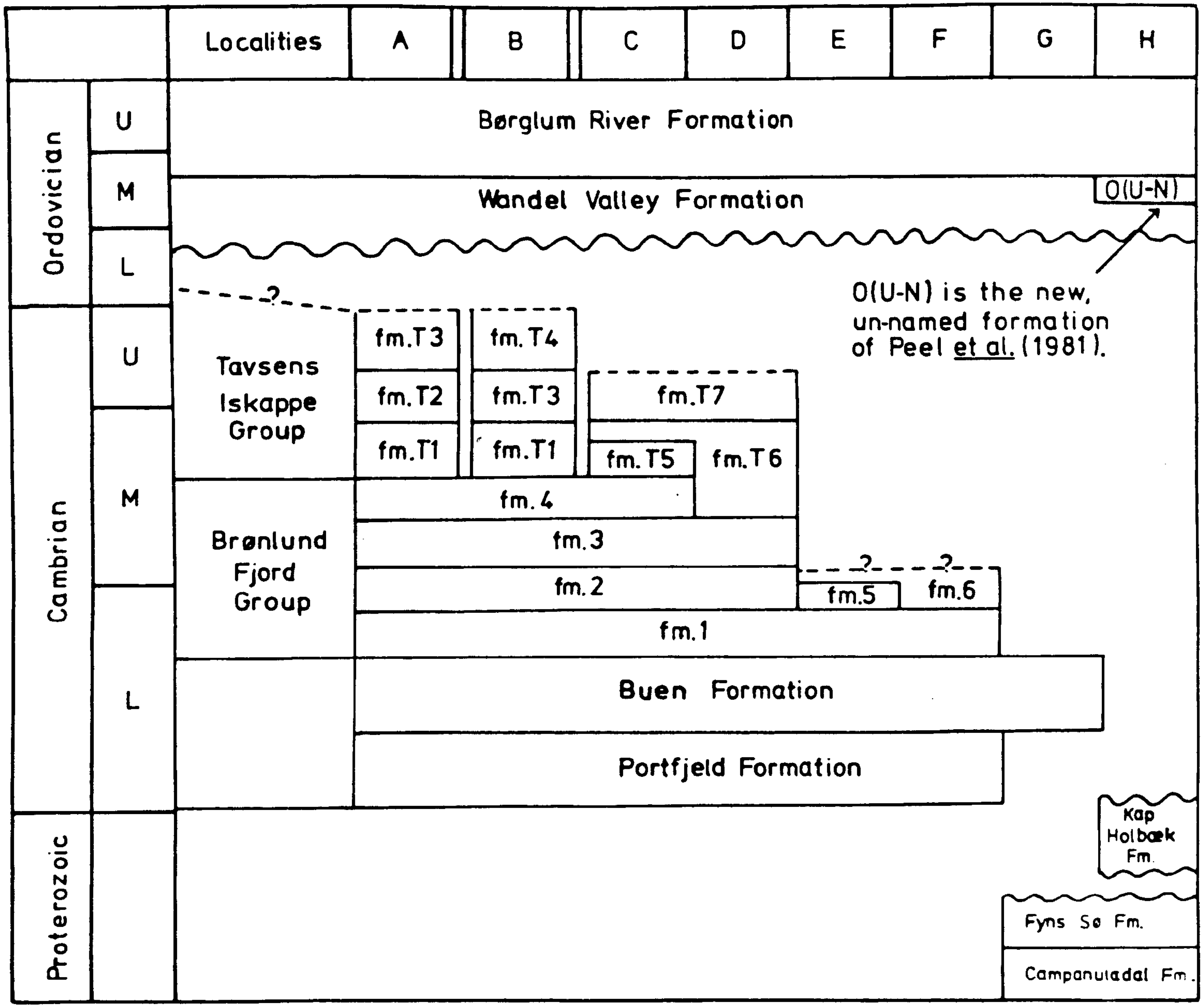


Fig. 3.1 Cambrian and Ordovician stratigraphy in southern Peary Land. Localities A-C, Hans Tavsens Iskappe; D-F, Peary Land; G, Hagen Fjord; H, Danmark Fjord. See fig. 3.2 for location of place names, (modified after Peel, in press)

Formation was commented upon. The Wandel Valley Formation has been most thoroughly described by Christie and Peel (1977) who divided the sequence exposed in Børglum Elv into three members:

Lower Member (45 - 50 m) A medium-grained, light grey dolomite. The lower 20 m is medium-bedded and is then finely laminated for 5 m. The remainder of the member is thick-bedded with chert common. Intraformational breccias are present in some beds and silt laminae are common, occasionally being truncated by small channels. Silicified fossils occur in patches.

Middle Member (30 m) The lower boundary of the member is transitional. The lithology is a dark grey to brown, mottled crystalline dolomite. The member is medium-bedded at the base and becomes thicker-bedded towards the top. Intraformational breccias are common and silt laminae are present. Chert is abundant, occurring as nodules and in beds. There are some carbonate/quartz-filled vugs.

Upper Member (c. 200 m) The member is thin to medium-bedded and recessive at outcrop. Silty laminae are common and may be contorted or truncated. Towards the top of the member, thinly-bedded black shales are interbedded with the dominant fine-grained pale grey dolomite. Euhedral laths of celestite in a dolomicrite matrix have been found at one horizon (GGU 227845, 227846) and stromatolites and mud-cracks have been recorded. Intraformational breccias are common. A 1.5 m thick slumped bed at 30 m serves as a useful marker horizon in Børglum Elv.

The sediments of the Wandel Valley Formation were interpreted by Hurst and Surlyk (1983) as representing deposition on a peritidal carbonate platform which was subjected to repeated rapid submergence, producing the shallow, subtidal, pelletal micrites, and subsequent rapid progradation, producing the very shallow subtidal and intertidal laminated and cryptalgal laminated dolomites. This alternation of submergence and progradation produces bed couplets.

The Wandel Valley Formation in Peary Land is overlain by mottled limestones of the Børglum River Formation and the boundary between the two is transitional. Macrofossils have suggested a Middle Ordovician age for the base of the Børglum River Formation and a late Ordovician age for the top (Peel, in press). The overlying "un-named Silurian dolomite" of Christie and Peel (1977) has yielded Richmondian conodonts in the lower 40 m (Armstrong, 1983).

The locations of sections collected in Peary Land, and their general geological relationships, are shown in Fig. 3.2., section logs and sample positions are illustrated in Fig. 3.3. The sections are briefly described here from west to east; full lithological descriptions were given by Christie and Peel (1977).

JSP 780711-1, JSP 780711-2 (East side of Hans Tavsens Iskappe, west Peary Land).

Collected by Dr. J.S. Peel through the upper 130 m of the upper member of the Wandel Valley Formation. Section line shown in Fig. 3.4. Sampling interval approximately 10 m.

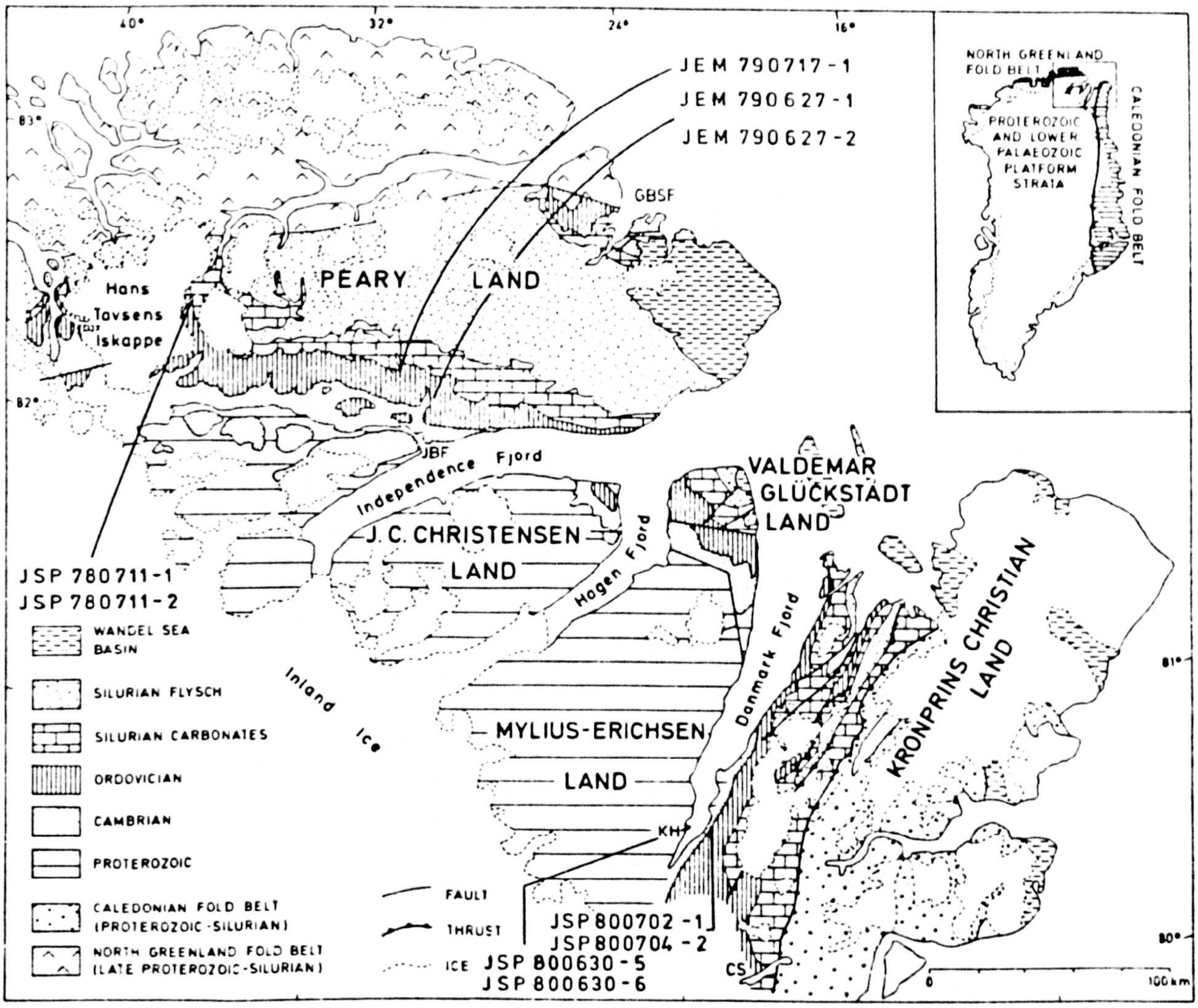


Fig. 3.2 Geological map of eastern North Greenland showing section localities (from Peel, in press)

JEM 790701-1 (Børglum Elv, central Peary Land)

Collected by Dr. J.E. Mabillard through the upper 118 m of the upper member of the Wandel Valley Formation at approximately 13 m intervals. The section line is shown in Fig. 3.5 and corresponds to Section G of Christie and Peel (1977).

JEM 790627-1 (Børglum Elv, central Peary Land)

Collected by Dr. J.E. Mabillard through the lower member (50 m), middle member (80 m) and the lower 180 m of the upper member of the Wandel Valley Formation. Collected in three profiles(Fig. 3.6); Profile 1 corresponds approximately to Section D of Christie and Peel (1977) and covers the lower, middle and lowermost part of the upper members. Profiles 2 and 3 are roughly equivalent in position to Section E of Christie and Peel (1977) and cover the upper and middle parts of the upper member respectively. Samples taken at 10 m intervals.

JEM 790627-2 (Børglum Elv, central Peary Land)

Collected by Dr. J.E. Mabillard through the upper 57 m of the upper member of the Wandel Valley Formation. The section is intermediate in position between Sections D and E of Christie and Peel (1977) and is shown on Fig. 3.6. Sampling interval is at 20 m intervals and at 2 - 3 m intervals near the upper boundary of the formation.

3.2.2. Lithostratigraphy of Kronprins Christian Land

In Kronprins Christian Land, 200 km to the south-east of Peary Land, the members of the Wandel Valley Formation differ in character from their counterparts in Peary Land (Peel *et al.*, 1981). A 10 - 12 m

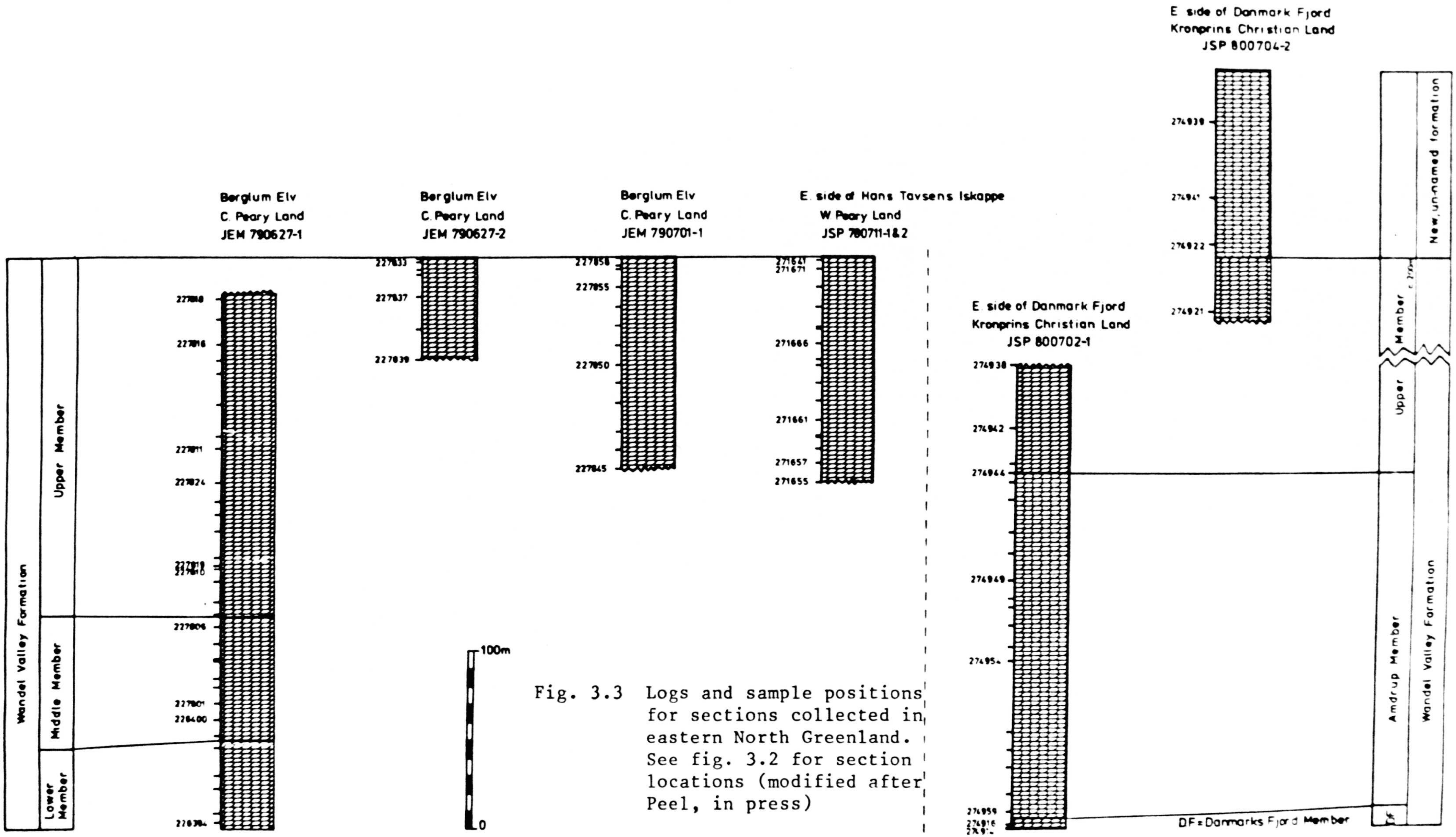


Fig. 3.3 Logs and sample positions for sections collected in eastern North Greenland. See fig. 3.2 for section locations (modified after Peel, in press)

dolomite overlying the Kap Holbaek Formation was given the name Danmarks Fjord Dolomite by Fränkl (1955) and originally thought to be Ordovician (Adams and Cowie, 1953, Fränkl, 1955) but was later reinterpreted to be equivalent to either the Brønlund Fjord Group (Cowie, 1971) or the upper part of the Portfjeld Formation and lower part of the Buen Formation (Poulsen, 1978). Peel et al. (1981) rejected both of these hypotheses and classified the unit as the basal member of the Wandel Valley Formation since a gradational boundary is seen east of Danmark Fjord. This interpretation of the succession has since been affirmed by the discovery of late Ibexian conodonts in the Danmark Fjord Member (Smith and Peel, in press).

A new, un-named Ordovician formation was recognised between the Wandel Valley Formation and the Børglum River Formation by Peel et al. (1981) and comprises a lower, dark, cliff-forming member and an upper, recessive member similar in lithology to the upper member of the Wandel Valley Formation. The upper member of the Wandel Valley Formation in Kronprins Christian Land and the lower part of the new formation are regarded by Peel (in press) as probable equivalents of the Opikina Limestone of Scrutton (1975). The new formation is tentatively correlated by Peel (in press) with the uppermost Wandel Valley Formation in Peary Land. The remainder of the Ordovician succession is the direct equivalent of those formations recognised in Peary Land (Peel et al., 1981).

The following lithological descriptions of the members of the Wandel Valley Formation and of the new, un-named formation are taken from Peel (in press) and from the notebooks and section logs of Dr J.S. Peel.

Danmarks Fjord Dolomite (6 - 12 m) A brown-weathering, fine to medium-grained, grey to dark grey dolomite. Black cherts, some with included ooids, are common. Laminated bedding is present and many develop into small, domal (LLH) stromatolites in the lower part of the unit. Intraformational breccias and oolites occur throughout. The lower boundary is erosional.

Amdrup Member (194 m) Mottled, bioturbated dolomitic micrite with lenticular black chert nodules. Dark grey to brown upon weathering. Scours filled with grainstones of pelbiosparite composition are common and are often associated with flat pebbles. Between 30 - 50m these units are particularly common and show cross-bedding. Bioturbation increases in the upper 10 m of the member. Fauna consists of gastropods, brachiopods, ostracods, trilobites and cephalopods.

Upper Member (200 m?) The lowermost part is heavily bioturbated, thin and flaggy, comprising dark grey dolomite that weathers to a mid-grey. Higher up the dolomite is paler, medium-bedded and bioturbated. Laminations, some silty, and flat pebble conglomerates with a grainstone matrix occur. Stromatolites and mudcracks are recorded.

Un-named Formation (105 m) The basal 5 m is a bioturbated, argillaceous limestone with flat pebble conglomerates. The overlying 15 m is a more massive, fine-grained, bioturbated micrite with thin bioclastic, intraformational conglomerates. The remainder of the 57.5 m dark-weathering member is 80 - 95% dolomite, which is medium-grained and burrow mottled. Occasional flat pebble conglomerate horizons occur. Trilobites and brachiopods have been recorded.

The remainder of the formation is a pale, silvery-grey dolomite with irregular, silty laminae and spar-filled vugs. At 75 m from the formation base is a 3 - 4 m interval with medium to thick-bedded, bioturbated, dark grey weathering dolomite with 1 - 10 cm ostracod coquinas in the lower 1 m. The lithology then reverts to pale, silvery grey dolomites with undulating silty laminae. The formation is overlain by typical, rubbly, dark brown to grey weathering dolomitic limestone of the Børglum River Formation.

Hurst and Surlyk (1983) consider the above sediments to have been deposited in a slightly deeper, more consistently subtidal, environment than those of Peary Land.

The sections collected in Kronprins Christian Land are described from west to east and located on Fig. 3.2. Section logs and sample positions are shown in Fig. 3.3.

JSP 800630-5, JSP 800630-6 (Kap Holbaek)

Four samples collected by Dr. J.S. Peel from the Danmarks Fjord Dolomite. Section location shown on Fig. 3.7.

JSP 800702-1 (East side of Danmark Fjord)

Collected by Dr. J.S. Peel through the Danmarks Fjord Dolomite (6 m), Amdrup Member (194 m) and the lower 60 m of the upper member. Section line shown on Fig. 3.7. Sampling interval 10 - 15 m.

JSP 800704-2 (East side of Danmark Fjord)

Section logged by Dr. J.S. Peel through the upper 35 m of the upper member of the Wandel Valley Formation, the new, un-named formation and the lower 15 m of the Børglum River Formation. Samples collected at 4 m, 77 m and 110 m. Section line shown on Fig. 3.7.

3.2.3. Macrofaunal Biostratigraphy of the Wandel Valley Formation

Troelson (1949) considered the Wandel Valley Formation to be of late, or possibly middle, Ibexian age (in current stratigraphic terms) on the basis of specimens of *Ceratopea* sp.recovered from the lower and middle members. These specimens were re-examined by Yochelson and Peel (1975) who determined the presence of *C. ankylosa* Cullison in the lower and middle members and the slightly younger *C. unguis* Yochelson and Bridge in the middle member. These indicate a late, but not latest, Ibexian age for the lower and middle members; *C. unguis* allows a correlation with the middle Nunatami Formation of Washington Land (Peel and Yochelson, 1979). Neither species occurs in Kronprins Christian Land but Peel (1980) documented the discovery of *C. billingsi* Yochelson from the Amdrup Member, a species known also from the Narwhale Sound Formation of East Greenland; it has also been recorded from Durness, in north-west Scotland, and Newfoundland. The relative stratigraphic position of this species is unfortunately unknown (Peel, 1980). Its presence in Kronprins Christian Land in the absence of the other species was attributed to the slightly more marine facies.

The trilobite found from the lower part of the Amdrup Member is closely similar to that found in the Catoche Formation of Newfoundland.

Similar faunas are also present in the Cape Weber Formation of East Greenland, the Nordporten Member of the Kirtonryggen Formation of Spitsbergen and in the Durness Limestone Group. Those elements of the fauna which extend into the midcontinent correlate with Zone H of the biostratigraphic scheme of Ross (1951) and Hintze (1952) (Fortey, 1982, GGU int. rept).

The very poorly fossiliferous upper member was inferred to be of Whiterock age by Christie and Peel (1977) since the underlying middle member is of upper Ibexian age and the overlying Børglum River Formation is Middle Ordovician.

3.2.4. Lithostratigraphical Correlation with Western North Greenland and Ellesmere Island

Rocks of early and middle Ibexian age appear to be absent in eastern North Greenland, but a more complete sequence is present in western North Greenland and Ellesmere Island (Kerr, 1968; Dawes, 1976). In these regions, formations of this age are of a generally regressive nature but limestones become dominant in the Canyon Elv and Nunatami Formations. The lower two members of the Wandel Valley Formation have been correlated with the uppermost part of the Canyon Elv Formation (purpley grey micrites) and the richly fossiliferous, grey weathering limestones and intraformational limestone conglomerates of the Nunatami Formation (Christie and Peel, 1982) which are in turn correlatives of the Eleanor River Formation of Ellesmere Island (Fig. 3.8).

The succeeding formations on Ellesmere Island and in Washington Land, the Bay Fiord and Cape Webster Formations respectively, both contain

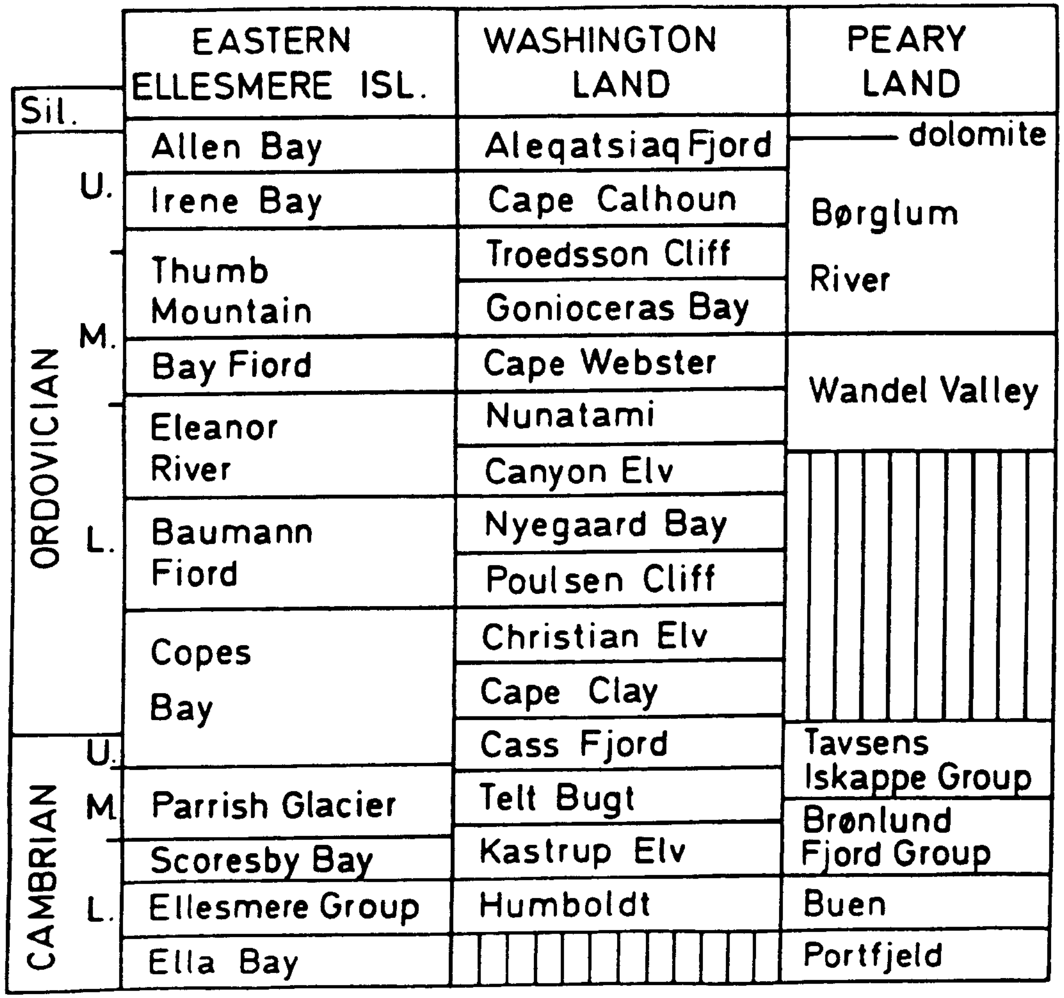


Fig. 3.8 Lithostratigraphical correlation of the Cambro-Ordovician of eastern Ellesmere Island, Washington Land (western North Greenland) and Peary Land (from Peel & Christie, 1982)

evaporites and are of a generally regressive nature with associated shales, siltstones and dolomites. These can be correlated with the pale, recessive dolomicrites of the upper member. Although this unit does not contain evaporites, hypersaline conditions are indicated by the presence of celestite laths in the dolomicrites (Olaussen, 1981), together with other shallow water indicators such as mudcracks, stromatolites and the very reduced fauna.

3.3. STRATIGRAPHY OF EAST GREENLAND

3.3.1. Lithologies and Lithostratigraphy

The lowest Ordovician formation in East Greenland is the Dolomite Point Formation, originally considered to be Middle Cambrian (e.g. Cowie, 1971) but which is now known to contain *Proconodontus* Zone conodonts (Miller and Kurtz, 1979) in the upper horizons. The succeeding Antiklinalbugt Formation (Peel and Cowie, 1979) is of lower Ibexian age and composed of thinly-bedded, nodular, muddy limestones with shaley partings.

The formations sampled for this thesis were first described by Koch (1929) who erected the Eskimo Hut and Cape Weber Formations. Poulsen (1930) subsequently found it necessary to revise these units in order to create a more detailed stratigraphy. The Cape Weber was redefined to include the upper part of the Eskimo Hut and the lower part of the Cape Weber Formations of Koch (1929) and the Narwhale Sound Formation was erected to cover the upper part of the Cape Weber Formation of Koch.

Cowie and Adams (1957) further refined the stratigraphic scheme and introduced a new formation, the Heim Bjerge Formation above the Narwhale Sound. The Heim Bjerge Formation is found only at the northern end of the outcrop belt where the basal Devonian unconformity truncates younger rocks than in the south.

The following account of lithologies is summarised from Cowie and Adams (1957).

Cape Weber Formation (1120 - 1165 m) Poulsen (1930) considered that the base of the formation was disconformable on an eroded surface of the Antiklinalbugt Formation. The Cape Weber Formation of Ella Ø and Albert Heim Bjerge was examined by Cowie and Adams (1957) who considered the relationship to be conformable. These authors divided the formation into three members but these members could only be broadly recognised in the present study, all boundaries being transitional. The lower 220 m of limestone are banded, with ½ - 2 m alternations of dark and light grey limestones. Some bedding planes are convex or hummocky, a feature attributed by Cowie and Adams (1957) to algal binding. Intraformational conglomerates are common and chert is a minor component.

The banded limestones are overlain by thick (680 m), massive grey limestones and dolomitic limestones which weather to a uniform pale grey. Black chert is very common, particularly in the upper half of the unit and occurs as blebs, stringers and thin bands. The top 220 m consists of massive grey limestones with extensive dolomitisation Cryptocrystalline masses of greyish silica are also common in the higher beds, but chert is common lower down.

Narwhale Sound Formation (462 m)

The junction of the Narwhale Sound Formation with the underlying Cape Weber is conformable and sharp. The full thickness of the formation is only seen in the northern part of the outcrop belt (Fig. 3.9); on Ella Ø the formation is truncated by the Middle Devonian "Basal Series" (Bütler, 1959); Henriksen and Higgins, 1976). The formation was divided into a lower unit of basal dolomites (70 - 112 m) and an upper unit of dolomitic limestones (350 m) by Cowie and Adams (1957). The basal dolomites are massive coarsely crystalline and vuggy with some silicification. These are interbedded with subordinate, medium-grey, fine grained dolomitic limestone. Towards the top, almost pure limestones are interbedded with the dolomites.

The junction between the two divisions is transitional and the boundary is taken where the coarsely crystalline dolomites end. The upper division consists of interbedded limestones and dolomitic limestones, with occasional dolomites. The dolomitic horizons vary from very fine-grained to coarse-grained and saccharoidal and from mid-grey to dark maroon-grey in colour. The unit has a banded appearance.

Heim Bjerge Formation (c. 1200 m)

Cowie and Adams (1957) recorded 320 m of uniform, massive, mid-grey micrites above the Narwhale Sound Formation on Albert Heim Bjerge (Fig. 3.9). Fine-scale intraformational conglomerates are frequent and the strata have a poor macrofauna. The Ordovician is once again truncated by the Middle Devonian red beds, although Mr. P. Frykman has recorded 540 m of Heim Bjerge Formation below the unconformity (PF 770713-1).

C.H. Ostenfeld Nunatak is the most northerly exposure of Cambro-Ordovician and was extremely poorly known until recently, having been visited only once, by J. Haller in 1956 (Cowie and Adams, 1957), when the presence of Precambrian strata, the Hyolithus Creek Formation and the Antiklinalbugt Formation was recorded. The locality was next visited in 1977 when Frykman (1979b) established the presence of a full sequence from the Hyolithus Creek Formation to the Heim Bjerge Formation, with a faulted contact between the base of the formation and the Precambrian. Furthermore, the Heim Bjerge Formation was found to be approximately 1200 m thick in a lithology identical to that seen on Albert Heim Bjerge, more than twice the thickness seen elsewhere. Peel (1982 b), therefore, speculated that Upper Ordovician may be present in East Greenland, but subsequent conodont studies indicated an Upper Whiterockian age for the youngest rocks present (Smith, 1982).

The sections studied in East Greenland are shown in their broad geographical context in Fig. 3.9 and section logs and sample positions are illustrated in Fig. 3.10. Sections are described below in stratiographic order and from south to north.

PF 770824-1 (Ella Ø)

Collected by Mr P. Frykman through the full thickness of the Cape Weber Formation and the lower part of the Narwhale Sound Formation up to the Ordovician - Devonian unconformity. The boundary between the banded limestones and the main limestones occurs between 150 and 200 m. The top of the main limestones is taken at the last abundant occurrence of chert before dolomites are recorded (970 m). The boundary between the Cape Weber and Narwhale Sound Formations is not seen, occurring in

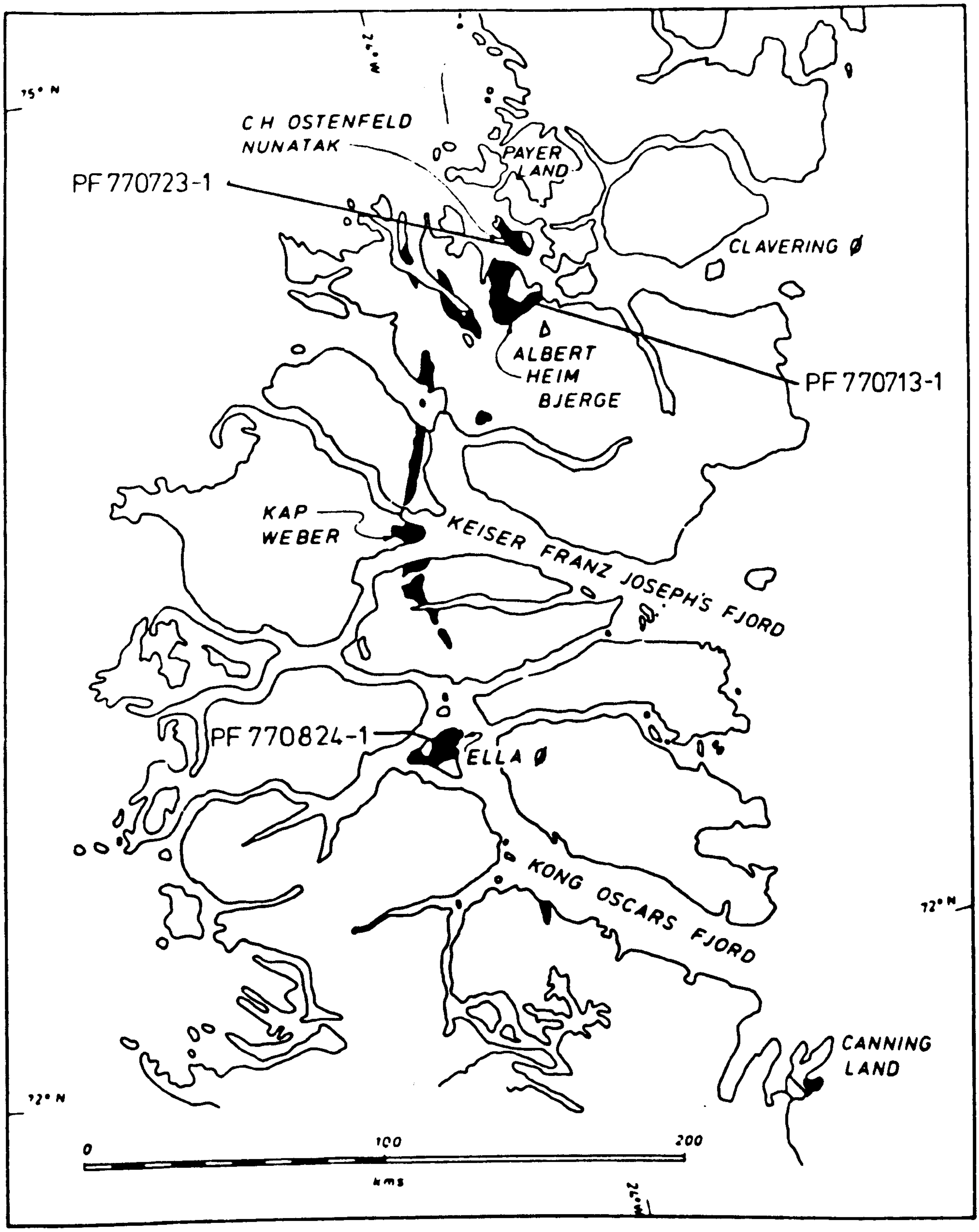


Fig. 3.9 Locality map for sections collected in East Greenland. Cambro-Ordovician outcrop belt shown in black

a 40 m unexposed section, but is taken at the highest exposure of characteristic lithologies of the Cape Weber Formation (1165 m). 230 m of strata typical of the Narwhale Sound Formation are recorded above 1165 m. White limestones are recorded at 1262 m and the last coarse, vuggy dolomite occurs at 1280 m. The section is located on Fig. 3.11. The average sampling interval is 17.5 m.

PF 770713-1 (Albert Heim Bjerge)

Collected by Mr P. Frykman through the upper 150 m of the Narwhale Sound Formation and all of the Heim Bjerge Formation below the unconformity (540 m). Section located on Fig. 3.12. The average sampling interval is 12 m.

PF 770723-1 (C.H. Ostenfeld Nunatak)

Collected by Mr P. Frykman through the upper 100 m of the Heim Bjerge Formation at 10 m intervals.

3.3.2. Lithostratigraphic and Macrofaunal Correlations

The sedimentology and diagenesis of the Cambrian and Lower Ordovician of East Greenland was investigated by Swett and Smit (1972 a) who concluded that the lithogical progression from sandstones to shales to limestones reflected increasing isolation from detrital sources rather than increasing water depths. Their conclusions on the environment of deposition were that sedimentation occurred in an intertidal to shallow subtidal water depth with sedimentation equal to subsidence.

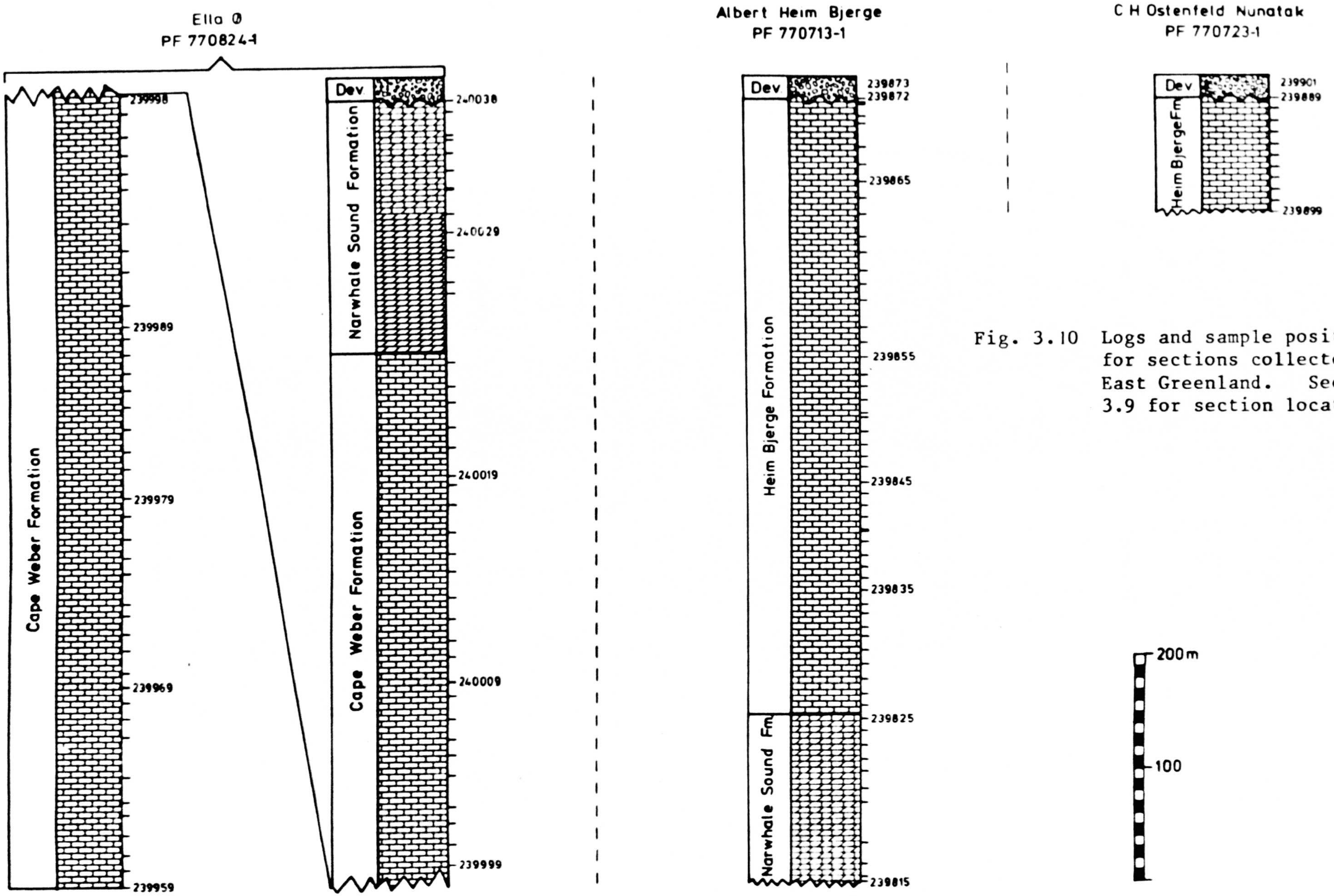


Fig. 3.10 Logs and sample positions for sections collected in East Greenland. See fig. 3.9 for section locations

Swett and Smit (1972 a, b) also noted a remarkable parallelism of the sequences through this interval from East Greenland, western Newfoundland and north-western Scotland. All of these areas have similar sandstone to dolomite successions but additionally have very similar petrographies, geochemistry and diagenetic history. Swett and Smit (1972 a, b) concluded that the three areas developed as contemporaneous and contiguous deposits on the northern margin of Iapetus. Swett (1981) further extended the correlation to Ny Friesland, Spitsbergen. The carbonate platform may have extended from Spitsbergen to Maryland.

Few diagnostic macrofossils have been recovered from the Cape Weber Formation although Cowie and Adams (1957) did list a fauna from their Black Limestones on Albert Heim Bjerge which they correlated with Zone J of Ross' (1951) zonation. Ceratopeltis latilimbata Poulsen has been found only in the Cape Weber Formation and the Amdrup Member of the Wandel Valley Formation (Fortey and Peel, 1983).

No clearly diagnostic macrofossils have been found in the Narwhale Sound Formation. Poulsen (1951) considered it to be Upper Canadian on the basis of some undescribed bathyurids but Cowie and Adams (1957) thought that it might equally be Champlainian when their age for the overlying Heim Bjerge Formation was taken into account.

Specimens of Rafinesquina cf. alternata Conrad, Opikina sp. and Receptaculites arcticus Etheridge found between 80 and 320 m up the Heim Bjerge Formation on Albert Heim Bjerge were considered to indicate a Trentonian age by Cowie and Adams (1957).

CHAPTER 4

TAXONOMY

4.1. APPARATUS NOTATION

The only part of the conodont animal which is normally preserved is the skeletal apparatus, which is composed of numerous elements of differing morphologies. Sometimes apparatuses can be recognised from natural assemblages, where the elements of an individual animal are preserved juxtaposed on bedding planes or fused together by diagenesis. Such assemblages can provide valuable evidence as to the relative positions of different element types within the animal (see Chapter 7). More often, however, apparatuses must be reconstructed from the discrete elements obtained by chemical breakdown of the sediment.

When reconstructing apparatus from isolated elements, features of each element such as range, abundance and the morphology of its cusp, denticles, basal cavity and white matter are compared. In addition, the apparatus under reconstruction can be compared with apparatus models established from natural assemblages or based on previously reconstructed species. Apparatus reconstructed in such a way do not attempt to include the elements present in any given individual but to demonstrate the range of element types in a given species irrespective of age, sex or any other factor which might be expected to distinguish individuals.

Although Hinde (1879) recognised that ".... whatever may have been the zoological relations of the animal it possessed a complicated and varied apparatus of teeth and plates", he chose to follow Pander (1856) and employ a more easily applied form taxonomy. This example was followed by other workers until attempts at reconstructing apparatuses from discrete elements were made by Walliser (1964) on Silurian faunas and Bergström and Sweet (1966) and Webers (1966) for the Ordovician. Since that time, numerous schemes have been devised for designating the elements of an apparatus and their positions relative to each other; the most commonly encountered being those of Jeppsson (1971), Klapper and Philip (1971), Sweet and Schönlaub (1975) and Barnes et al. (1979) Of these methods of notation it is that of Sweet and Schönlaub (1975) which has achieved the widest acceptance, at least for ramiform-pectiniform apparatus. In the slightly modified form presented by Sweet (1981), elements may be described in terms of Pa and Pb pectiniform elements, ramiform M elements and a symmetry transition series of Sa, Sb, Sc and Sd ramiform elements. Sweet (1981) also proposed a number of morphological terms to describe ramiform and pectiniform elements.

Apparatus composed of coniform elements present a more difficult problem. The notation of Sweet and Schönlaub (1975) has been applied to coniform apparatuses, notably by Barrick (1977), Orchard (1980) and Cooper (1981), but homology with the respective elements of ramiform apparatuses is by no means demonstrable. In particular, there is no evidence that the elements assigned to the P position in coniform species (Orchard, 1980; Cooper, 1981) occupied a position discrete from the S elements as is known to be the case in ramiform apparatuses (Briggs et al., 1983).

The system of notation here applied to coniform apparatuses is the only one which has been specifically designed for such species. Barnes *et al.* (1979) divided conodont apparatuses into five types. Types II, IV and V are ramiform apparatuses but the notation of Type I and III apparatuses is followed here to describe coniform species.

Type IA apparatuses (Fig. 4.1) may contain up to three basic element types; the s element is symmetrical in cusp cross-section and may be laterally compressed, the t element is asymmetrical and the u element is symmetrical but compressed antero-posteriorly. The elements may form a smooth transition series with intermediate element morphologies (e.g. *Juanognathus*) or there may be distinct morphological breaks (e.g. *"Scolopodus" gracilis*), Type IB apparatuses are similar to Type IA apparatuses but lack one element type, usually the u element (e.g. *Glyptoconus*), Type IC apparatuses have only a single, s, element.

Type III apparatuses (Fig. 4.2) are subdivided by cusp recurvature rather than cusp cross-section. Again up to three elements may constitute the apparatus; p elements are erect to weakly recurved, q elements are moderately to markedly recurved and r elements are sharply reclined and often of geniculate morphology.

It has remained impossible to include some coniform genera within either of the above apparatus types. In such cases informal, descriptive terms are used to describe the element types. The term is usually based upon a representative form genus or species with the suffix -iform appended. Wherever possible the terms used are

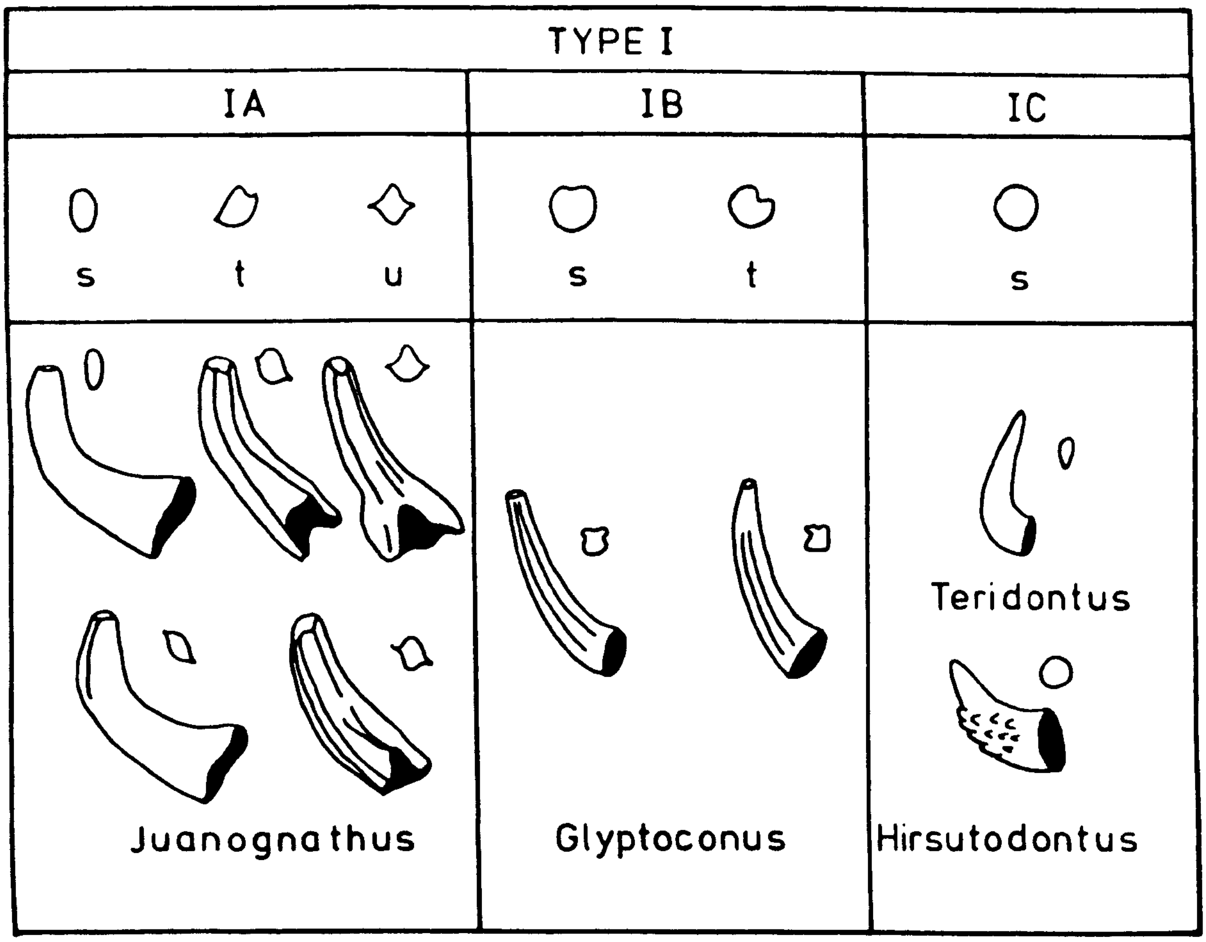


Fig. 4.1 Structure, with examples, of apparatus Type I, with subtypes IA, IB, and IC (modified after Barnes *et al*., 1979)

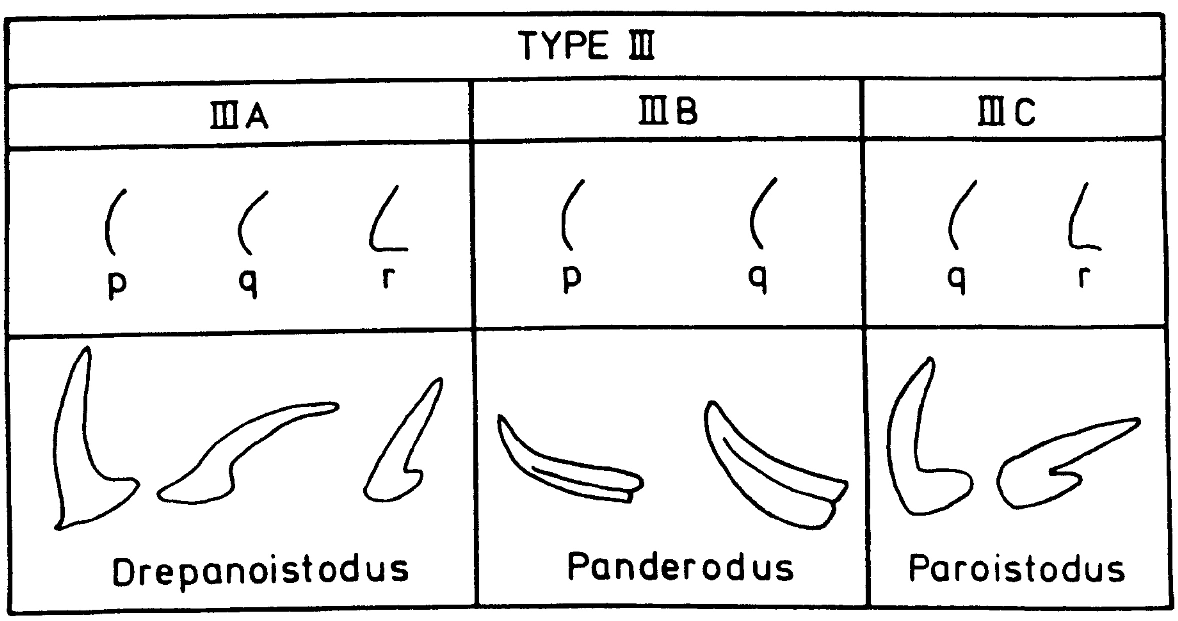


Fig. 4.2 Structure, with examples, of apparatus Type III, with subtypes IIIA, IIIB and IIIC (modified after Barnes *et al*., 1979)

those most commonly applied in the literature. Thus, *Drepanodus* is divided into arcuatiform, sculponeaform, pipaform and graciliform elements (after Lindström, 1971; van Wamel, 1974).

4.2. SUPRAGENERIC CLASSIFICATION

The classification of conodonts at family level and above has been attempted by numerous authors since the earliest efforts of Bassler (1925) and Ulrich and Bassler (1926). The first attempt to erect a "natural", biological classification of multielement genera was that of Lindström (1970). This system was expanded in the Treatise on Invertebrate Paleontology (Clark, 1981) so that 180 of the 240 genera described were included in the classification. In this thesis, however, higher level classification is not used. The principal reason is that several of the genera recovered belong in the group of sixty which were included under "Family Unknown" in the Treatise. Others have been described subsequent to its publication and, of these, several cannot be accommodated in the classification as it stands. The genera are thus arranged in alphabetical order.

4.3. OPEN NOMENCLATURE AND SYNONOMY LIST ANNOTATION

The system of open nomenclature adopted is essentially that of Richter (1948) as reviewed by Matthews (1973) although it is pertinent to detail the precise usage of each of the terms.

sp. nov. A	The species concerned is new but due to lack of material or an inadequate knowledge of the apparatus it is not yet justifiable to erect one.

aff.	The species in question is probably new but formal establishment is not yet justifiable and it is associated, for the time being, with a related species.
cf.	The species is probably that named but lack of material prohibits a more decisive assignment.
?	If placed after the genus,? denotes that attribution to that genus is uncertain and similarly with the species if placed after the species name. A ? before the binomen denotes that attribution to both the genus and the species is uncertain.

Other methods not used by Richter (1948) or Matthews (1973) have been utilised and are as follows:-

"genus"	The genus in question is being used in either the form-generic sense or, more usually, the species in question will almost certainly need to be reassigned to a new genus with time but it is at present considered premature to do so.
sp.A	The species is consistently recognisable but lack of material or poor preservation means that it is not possible to discuss whether the taxon is new or has been previously described.

eobelodiniform 1	In a few cases, elements corresponding to well known form categories, such as cordylodiform, eobelodiniform or scandodiform have been referred to as such and a number is appended. In such cases the elements are present in low numbers and the morphologies are common to several genera.

The annotation of synonomy lists follows Richter (1948) and Rabien (1954) as reviewed and criticised by Matthews (1973).

SYSTEMATIC PALAEONTOLOGY

Genus ACONTIODUS Pander, 1856

1856 *Acontiodus* Pander, p. 28

Type Species: *Acontiodus latus* Pander, 1856.

Remarks: All of the species here included in *Acontiodus* will eventually need assigning to other genera, some possibly new. *Acontiodus* was considered by Austin *et al.* (1981) to be a possible junior synonym of *Acodus* Pander although Kennedy (1980) considered *Acodus* itself to be a nomen dubium (see *Diaphorodus* Remarks). "*Acontiodus*" is here used as a form taxon.

"Acontiodus" stauffericus Furnish, 1938

Pl. 1, Figs 1, 2

	1938	*Acontiodus staufferi* Furnish; p. 326, pl. 42, Figs 11-12, text-fig. 1K.
non	1964	*Acontiodus staufferi* Furnish; Ethington and Clark, p. 687-88, pl. 113, Figs 4, 9.
non	1965	*Acontiodus staufferi* Furnish; Ethington and Clark, pl. 2, Fig. 14.
non	1965b	*Acontiodus staufferi* Furnish; Mound, p. 12-13, pl. 1, Fig. 22.
?p	1968	*Acontiodus staufferi* Furnish; Mound, p. 408, pl. 1, Fig. 39 only (non Figs 36-38, 40-49).

1970 Acontiodus staufferi Furnish; Barnes and Tuke, p. 84, pl. 19, Figs 2, 3.

1971 Acontiodus staufferi Furnish; Ethington and Clark, pl. 1, Fig.14.

non 1971 Scolopodus staufferi (Furnish); Druce and Jones, p. 94-95, pl. 18, Figs 8-9.

non 1971 Scolopodus staufferi (Furnish); Jones, p. 67, pl.6, Fig. 7.

non 1971 Acontiodus staufferi Furnish; Greggs and Bond, p. 1463, pl. 1, Figs 1, 2.

1975 Acontiodus staufferi Furnish, Abaimova, p. 51-52, pl. 2, Figs 1, 2.

1980 Acontiodus staufferi Furnish; Kennedy, pl. 2, Fig. 38.

1980 Acontiodus iowensis Furnish; Grether and Clark, pl. 1, Fig. 46.

1980 Acontiodus staufferi Furnish; Grether and Clark, pl. 1, Fig. 49.

1982 "Acontiodus" staufferi Furnish; Ethington and Clark, p. 24, pl. 1, Fig. 24.

1982 Acontiodus staufferi Furnish; Repetski, p. 15, pl. 4, Figs. 4a - 5d.

p 1982 Scolopodus staufferi (Furnish); Moskalenko, p. 139-140, pl. 25, Fig. 14 only (non Figs 10a & b).

Remarks: "A." staufferi was first described by Furnish (1938) from the Shakopee Dolomite of Wisconsin, and included specimens with an unmodified posterior carina and others with bifid posterior costae. Many subsequent identifications of this species have been erroneous. Specimens described by Ethington and Clark (1964) are here described as "Acontiodus" sp.A. The material most closely similar to that from Greenland was described by Barnes and Tuke (1970).

Druce and Jones (1971) placed those species included in Acontiodus by Furnish (1938) within Scolopodus Pander because of their costate nature and generally hyaline cusp. However, they are not similar to any elements in the apparatus of the type species, S. sublaevis Pander, as reconstructed by Fahraeus (1982).

Landing (1981) and Landing and Barnes (1981) included "A." staufferi in the apparatus of Glyptoconus quadraplicatus (Branson and Mehl) together with Scolopodus robustus of Ethington and Clark (1964). A similar style of apparatus was proposed by Nowlan (1976) in an unpublished PhD thesis. A. staufferi was considered by Nowlan to be conspecific with specimens here described as Utahconus? bassleri (Furnish). The ranges of "A." staufferi and U? bassleri differ considerably and they are unlikely to be part of the same apparatus. It is also unlikely that "A." staufferi belongs with G. quadraplicatus in view of the extreme sparsity of "A." staufferi elements. I therefore prefer to retain "A." staufferi as a form taxon for the present.

Range: "A." staufferi occurs up to 30 m in the Wandel Valley Formation in Børglum Elv and up to 55 m in Kronprins Christian Land; also from 76 to 543 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 28

"Acontiodus" sp. A.

Pl. 1, Fig. 3

1964 Acontiodus staufferi Furnish; Ethington and Clark, p. 687, pl. 113, Figs 4, 9.

1982 Scolopodiform C; Ethington and Clark, p. 107, pl. 12, Fig. 14, text-Fig. 29.

Remarks: These specimens differ from "A." staufferi in being more antero-posteriorly compressed, having sharper posterior costae and lacking the flared and lipped basal margin.

Range: "A." sp. A. ranges from 12 m to 45 m in the Wandel Valley Formation of Kronprins Christian Land and occurs at 128 m in Børglum Elv. The species is also found at 424 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 5

"Acontiodus" sp. B.

Pl. 1, Fig. 4

1982 "Acontiodus" propinquus Furnish; Ethington and Clark, p. 24, pl. 1, Fig. 24.

? 1983 Scolopodus staufferi (Furnish); Ni in Zeng et al., pl. 12, Fig. 37.

Description: Cusp erect to slightly proclined. Anterior margin rounded. Lateral faces flat, conveying anteriorly, terminated posteriorly by postero-lateral costae. Posterior face concave or with a shallow, v-shaped groove.

Basal outline approximately circular. Basal margin straight or lipped. Basal cavity moderately deep, conical, apex just anterior of centre. Hyaline, may be faintly striate.

Remarks: The morphology is similar to "A." propinquus Furnish but, as noted by Landing and Barnes (1981), the type specimens are albid whereas these are hyaline. Furthermore, no specimens with a median posterior costa, as illustrated by Furnish (1938), were recovered from Greenland.

The specimens described as "A." propinquus by Ethington and Clark (1982) are very similar to "A." sp. B. and, from their remarks, appear to be hyaline. "A." sp. B. may prove to be a posteriorly acostate component of the apparatus of A. staufferi since the overall morphology of the two elements is very similar.

Range: "A." sp. B. occurs from the base up to 121 m in the Wandel Valley Formation in Børglum Elv and at 45 m in Kronprins Christian Land. A single specimen was found at 76 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 8

Genus AMORPHOGNATHUS Branson and Mehl, 1933

1933 *Amorphognathus* Branson and Mehl, p.126

Type Species: *Amorphognathus ordovicicus* Branson and Mehl, 1933

Amorphognathus? sp. A

Pl. 1, Figs 5, 6

Remarks: This species is represented by a stelliplanate element with a denticulate anterior process and an adenticulate posterior process which subtends an angle of approximately 110° with the anterior process. The inner lateral process is short and denticulate. The outer lateral process is larger and bifurcates; the margin between the bifid processes is serrate. No associated ramiform elements were found.

The element does not closely resemble any previously described species of *Amorphognathus* but is included on the basis of its scaphate morphology. The two other common Middle Ordovician platform elements, of the genera *Polyplacognathus* and *Eoplacognathus*, are both planate.

Range: From 100 to 90 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 3

Genus APPALACHIGNATHUS Bergström et al. 1974

1974 Appalachignathus Bergstrom, Carnes, Ethington, Votaw and Wigley, p.227

Type Species: Appalachignathus delicatulus Bergström et al., 1974

Appalachignathus delicatulus Bergström et al., 1974

Pl. 1, Figs 7 - 13

* 1974 Appalachignathus delicatulus Bergström, Carnes, Ethington, Votaw and Wigley, p. 228 - 235, pl. 1, Figs. 1-10, text-Figs 1-3 (synonomy to 1969)

1977 Appalachignathus sp.; Barnes, p. 105, pl. 4, Fig. 1.

? 1978 Appalachignathus delicatulus Bergström et al.; Tipnis, Chatterton and Ludvigsen, pl. 6, Figs 5-10.

Remarks: The apparatus of A. delicatulus was first reconstructed by Bergström et al. (1974), there having been few previous descriptions of its constituent elements (Webers, 1966; Ethington and Schumacher, 1969) Bergström et al. (1974) included Pa and Pb elements and an Sa - Sc transition series. This concept was modified by Bergström (1981) who included a symmetry transition series of four elements and a seventh element, possibly an M.

In the present study, the P elements were commonly recovered as fragments Pa and Pb element fragments could not be readily differentiated and are hence grouped together. The Sa element generally conforms to the description given by Bergström et al. (1974) except that some specimens have a bifid posterior costa. The Sb element may be sub-divided into two types, one similar to that described by Bergström et al. and a second, more fan-shaped, element with the lateral processes adjoining each end of the narrow basal cavity. The two element morphologies seem to intergrade in the small number of specimens available. The Sc element compares with that of Bergström et al. but an additional element, possibly an S, was not described by those authors. The element is laterally compressed and has a denticulate posterior margin and an anterior margin that is denticulate distally.

Range: From 22 m below the top of the Wandel Valley Formation into the Børglum River Formation in central Peary Land. It occurs in the uppermost 70 m of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak and in a single sample 386 m up section PF 770713-1.

Number of Specimens: 24 P, 9 Sa, 7 Sb, 3 Sc, 2 S?

Genus BELODELLA Ethington, 1959

1959 Belodella Ethington, p. 271

? 1969 Tokognathus Nieper, p. 012

1973 Haplobelodella Khodalevich and Tschernich, p. 43

Type Species: Belodus devonicus Stauffer, 1940.

Remarks: The apparatus of Belodella shows marked changes through its long range. The oldest species, B. jemtlandica Löfgren, occurs in the uppermost lower Ordovician and consists of triangular, plano-convex, biconvex and oistodiform elements (terminology of Löfgren, 1978). Subsequent species, middle Ordovician B. nevadensis Ethington and Schumacher and upper Ordovician B. erecta Rhodes and Dineley, develop a denticulate posterior margin on the biconvex element.

Silurian species have a rather different apparatus structure in which the oistodiform element is absent (Armstrong, 1983) or much modified (Barrick, 1977). Upper Silurian and Devonian species of Belodella may also loose the biconvex element, for example B. devonica Stauffer (Cooper, 1974).

As a consequence of these changes in apparatus plan with time, several origins have been proposed for the Siluro-Devonian Belodella lineage, mainly prior to the full description of the Ordovician species. Schwab (1969) considered the lineage to have arisen from the development of denticulation in Panderodus. This was refuted by Cooper (1975) who considered the Silurian species of Belodella to have evolved from

Walliserodus curvatus (Branson and Branson), as did Rexroad and Craig(1971). Now that the stratigraphic gaps are being closed (Ethington and Clark, 1982; Armstrong, 1983) it is more likely that Belodella does, in fact, represent a single lineage ranging from lower Ordovician to Devonian.

Belodella robusta Ethington and Clark, 1982

Pl. 2, Figs 1 - 8

1979 Belodella nevadensis (Ethington and Schumacher); Harris et al. pl. 3, Figs 10-13.

? 1980 Belodella erecta (Rhodes and Dineley); Lee, pl. 2, Fig.12.

? 1980 Oepikodus copenhagenensis Ethington and Schumacher; Lee, pl. 2, Fig. 13.

* 1982 Belodella robusta Ethington and Clark, p. 25-27, pl. 2, Figs 1-4, (synonomy to 1979).

1982 Belodella (?) sp.; Moskalenko, p. 103-4, pl. 18, Figs 18a, b.

p 1982 Belodella spp.; Stouge, pl. 6, Figs 2, 3, 7, (? 4, 6), (non 5, 8).

Remarks: Ethington and Clark (1982) included in this species those apparatuses of Belodella which contained an oistodiform element, an adenticulate biconvex element with sharp, lateral costae and triangular and plano-convex elements with robust, erect denticles.

The collections of B. robusta from Greenland show some variation in morphology. The triangular element is almost always symmetrical but occasionally one antero-lateral costa is situated in a more lateral position. A small number of triangular elements have a long base and are narrower from anterior margin to posterior margin. Denticles on the triangular and plano-convex elements vary from being stout and even-sized to relatively fine and irregular. The biconvex element is most commonly smooth along its posterior margin but Ethington and Clark (1982) mentioned that some specimens had prisms normal to the posterior margin. Some Greenland specimens have a minutely serrate posterior margin. The lateral costae may be sharply rounded rather than sharp.

Ethington and Clark (1982) questionably included in synonomy *Belodella* sp. A. and *B.*sp. B of Serpagli (1974). The fauna described by Serpagli is of late Ibexian age, containing *Bergstroemognathus extensus* and *Oepikodus smithensis*. *B.*sp. A closely resembles the plano-convex element of *B. robusta* and *B.*sp. B the triangular element. If *B. robusta* is proven to extend into the Ibexian it will be intermediate in both age and morphology between *B. jemtlandica* Löfgren and *B. nevadensis* Ethington and Schumacher. *B. robusta* differs from *B. jemtlandica*, the only unequivocal lower Ordovician representative, in having coarser, more uneven denticulation and a laterally costate biconvex element. It differs from *B. nevadensis* in having coarser, erect denticles on the triangular and plano-convex elements, an adenticulate biconvex element and an oistodiform element with a shallower basal cavity and a base that is shorter posteriorly.

Moskalenko (1982) figures a biconvex element as *B.*(?) sp. but did not illustrate any other elements of the apparatus. Stouge (1983) figured six elements of *Belodella* but did not assign them to species. Those described as proclined adenticulate elements (pl. 6, Figs 3, 7) are biconvex elements of B. robusta and one of his symmetrical adenticulate elements (pl. 6, Fig. 2) is a triangular element of this species with coarse, erect denticles. The remaining triangular element and the oistodiform (pl. 6, Figs 4, 6) may belong to B. robusta but do not have sufficiently diagnostic morphologies. The asymmetrical denticulate element of Stouge (1983, pl. 6, Figs 5, 8) are plano-convex elements of B. nevadensis (cf. Ethington and Schumacher, 1969, pl. 68, Fig. 14).

Range: In central Peary Land B. robusta first appears 286 m above the base of the Wandel Valley Formation and last occurs 3 m below the top. It occurs at 7 m and 33 m in the new, un-named Ordovician Formation in Kronprins Christian Land. On Albert Heim Bjerge, B. robusta occurs from 288 m above the base of the top of section PF 770713-1 and occurs in the upper 100 m of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Numbers of Specimens: 84 triangular, 49 plano-convex, 45 biconvex, 37 oistodiform.

Belodella? sp. nov. A

Pl. 2, Figs 9 - 11

Description:

Triangular element

Cusp erect. Anterior face broadly rounded, bounded by sharp, antero-lateral costae. Posterior face bears two low, rounded costae, with narrow groove between; costae continue along upper edge of base. Antero-lateral costae diverge at cusp/base junction where the anterior face is indented and v-shaped. Lateral face broadly rounded, rounded groove situated just posterior of antero-lateral costae. Cusp and base lengths approximately equal. Denticles long and needle-like with small, irregularly-sized ones interspersed.

Basal cavity very deep, sharply conical, posterior margin parallel to upper edge of base, anterior margin at acute angle to anterior margin of cusp, apex situated at point of maximum recurvature.

Plano-convex element

Cusp morphology similar to triangular element but at cusp/base junction the antero-lateral costae merge to form narrowly rounded anterior margin of base. Lateral face anterior of basal cavity flat, strongly convex across cavity. Upper edge of base longer than on triangular element. Denticles short, discrete and peg-like.

Biconvex element

Cusp erect to recurved, posterior margin sharp, curving evenly into short, sharp, adenticulate upper edge of base. Anterior margin sharp. Lateral faces each bear a very prominent, high, narrow costae posterior to the midline on cusp, more anterior on base. Costae directed posteriorly on cusp, twisting round to face anteriorly on base, extended beyond margin as short, antero-laterally directed processes. Anterior part of lateral faces may bear low ridges adjacent but oblique to anterior margin.

Basal cavity deep, anterior margin in same position as antero-lateral costae, posterior margin parallel to upper edge of base.

Remarks: The elements of B? sp. A. have a characteristic morphology but do not comply exactly with the terminology used by Lofgren (1978). This, however, is used to facilitate comparison with other species.

The plano-convex element differs from those of other Ordovician species in having a pair of antero-lateral costae on the cusp and a characteristically swollen basal cavity. The biconvex element is distinctive in having the lateral costae produced as short processes. The latter could, however, be quite easily developed from the bicostate biconvex element of *B. robusta*. Oistodiform elements are not recognised in the apparatus.

The species is questionably assigned to *Belodella* because, in such a small collection, it cannot be demonstrated that the biconvex element is definitely associated with the other two elements. In addition, all other Ordovician species of *Belodella* possess an oistodiform element.

Range: From 22 to 13 m below the top of the Wandel Valley Formation in Central Peary Land. The species occurs between 448 m and 690 m above the base of PF 770713-1 and 90 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 4 triangular, 5 plano-convex, 3 biconvex.

Genus BELODINA Ethington, 1959

1959 *Belodina* Ethington, p. 271.

1959 *Eobelodina* Sweet *et al*., p. 1050

Type Species: *Belodus grandis*, Stauffer, 1935.

Belodina monitorensis Ethington and Schumacher, 1969

Pl. 2, Figs 12, 13

* 1969 *Belodina monitorensis monitorensis*, Ethington and Schumacher, p. 456, pl. 67, Figs 3, 5, 8, 9.

1969 *Belodina monitorensis marginata*, Ethington and Schumacher, p. 456, pl. 67, Figs 1, 2, 4, 6.

1967 *Eobelodina occidentalis*, Ethington and Schumacher, p. 462-3, pl. 67, Figs 16, 20, text-Fig. 5H.

Remarks: Ethington and Schumacher (1969) distinguished *B. monitorensis* from other species of *Belodina* by the presence of prominent costae on the lateral faces, a broad cusp and a short, high heel. The Greenland specimens of rastrate elements compare closely to those figured as *B. monitorensis marginata* by Ethington and Schumacher (1969, pl. 67, Figs 4, 6) although they have a rather shorter heel.

Range: From 90 to 30 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 6 rastrate, 4 eobelodiniform.

eobelodiniform 1

Pl. 2, Figs 14, 15

Remarks: Included in this group are eobelodiniform elements typical of *Belodina*, which occur in the Heim Bjerge Formation but which are not associated with the diagnostic rastrate elements. They do not occur within the range of *B. monitorensis*.

Range: From 398 to 528 m in PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 7

Genus BERGSTROEMOGNATHUS Serpagli, 1974

1974 Bergstroemognathus Serpagli, p. 39

Type Species: Oistodus extensus Graves and Ellison, 1941

Bergstroemognathus extensus (Graves and Ellison, 1941)

Pl.2, Figs 16 - 22

* 1941 Oistodus extensus, Graves and Ellison, p. 13, pl. 1, Figs 16, 28.

? 1972 Rhipidognathus? n.sp.; Bergström et al., text-Fig. 1K.

1974 Bergstroemognathus extensus (Graves and Ellison); Serpagli, p. 40-43, pl. 9, Figs 1-8, pl. 21, Figs 1-7, text-Fig. 6.

1976 Bergstroemognathus cf. B. extensus (Graves and Ellison); Landing, p. 40, pl. 1, Figs 1-6, 9, 10.

? 1981 Bergstroemognathus extensus (Graves and Ellison); Cooper, p. 161, pl. 31, Fig. 12, pl. 32, Figs 7, 9-11.

1982 Bergstroemognathus extensus (Graves and Ellison); Bultynck and Martin, pl. 1, Fig. 2.

1982 Bergstroemognathus extensus Serpagli (sic); Stouge, pl. 6, Figs 1-4.

1983 Bergstroemognathus extensus Serpagli (sic); Stouge, pl. 4, Figs 15, 16.

1983 Bergstroemognathus extensus (Graves et Ellison) (sic); Ni in Zeng et al., pl. 11, Figs 9-13.

Remarks: The trimembrate apparatus consists of alate, segminate and bipennate elements. Berstrðm (1981) considered the third element to be tertiopedate but the third, lateral, process, is simply a downward extension of the basal margin rather than a true process. The morphology of the alate and segminate elements is consistent with previous descriptions in all but denticle numbers. The Greenland specimens have up to twelve denticles on the alate element and eighteen on the segminate element. This is rather more than on those described by Serpagli (1974) who cited up to seven and twelve denticles respectively.

The bipennate element is variable both in terms of symmetry and denticulation. The anterior process is always denticulate, bearing from two to five denticles. The posterior process may be adenticulate and bear a thin keel or have up to three denticles. If a keel is present, small incipient denticles may be found at its anterior end. The anterior and posterior processes may be in the same plane or the element may be strongly laterally bowed. Studies on larger collections may show that a systematic transition takes place within this element.

The specimen figured by Bergström et al. (1972) is fragmentary but may be part of an alate element. The specimens figured by Cooper (1981) differ in having broader, more laterally discrete denticles and may represent a different species. Bultynck and Martin (1982) illustrated a typical segminate element. The two bipennate specimens figured by Stouge (1982) have very well developed anterior processes and extremely short posterior processes. This type of element has also been recovered from Greenland. In addition to the references cited in the synonomy list, B. extensus has also been reported from Washington Land (Kurtz and Miller, GGU int. rept.).

Range: B. extensus occurs between 916 m and 1052 m up to the Cape Weber Formation on Ella Ø and ranges from 103 m to 195 m in the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 23 segminate, 5 alate, 36 bipennate.

Genus CHOSONODINA Müller, 1964

1964 *Chosonodina* Müller, p. 99

Type Species: *Chosonodina herfuthi* Müller, 1964

Chosonodina rigbyi Ethington and Clark, 1982

Pl. 3, Fig. 1

* 1982 *Chosonodina rigbyi* Ethington and Clark, p. 29, pl. 2, Figs 3, 11, (synonomy to 1979).

Remarks: Only two poorly preserved specimens of this species were recovered. They correspond to those of Ethington and Clark (1982) in having denticles fused almost to the apices, inter-denticular grooves developed only on the concave face and being only gently bowed.

Range: Found 168 m above the base of the Wandel Valley Formation in central Peary Land but is also known to occur in the lower part of the Narwhale Sound Formation on Albert Heim Bjerge (unpublished GGU collections).

Number of Specimens: 2

Genus CORDYLODUS Pander, 1856

1856 *Cordylodus* Pander, p. 33

Type Species: *Cordylodus angulatus* Pander, 1856.

Remarks: Miller (1980) reviewed the taxonomy of *Cordylodus* and proposed the terms rounded and compressed for the elements of the bimembrate apparatus, in reference to the cusp cross-section. These terms are used below.

Cordylodus sp. nov. A

Pl. 3, Fig. 2

Remarks: There are several characteristic features distinguishing compressed elements of *C.* sp.nov.A from those species described previously (Miller, 1980; Ethington and Clark, 1982; Repetski, 1982). The basal cavity is extremely shallow and extends posteriorly as a slit to the end of the posterior process; the basal margin, from the antero-basal corner to the end of the posterior process, is straight and there is a noticeable increase in the reclination of the denticles posteriorly. The rounded element is too poorly preserved to permit comparison with previously described material.

Range: The species was found in a single sample 15 m up the Cape Weber Formation on Ella Ø.

Number of Specimens: 3 compressed, 1 rounded.

"*Cordylodus*" sp. B

Pl. 3, Figs 3 - 9

1978 *Cordylodus* sp. A; Tipnis, Chatterton and Ludvigsen, pl. 4, Fig. 22.

p 1982 *Erraticadon* aff. *E. balticus* Dzik; Ethington and Clark, p. 45, pl. 4, Fig. 17 only, (non Figs 15, 23, 24).

Description:

Sa element

Cusp reclined to recurved, anterior margin rounded, lateral faces broadly rounded, three costae situated postero-laterally and posteriorly; costae sharp, narrow and low. Postero-lateral costae join lateral processes produced from posterior margin of basal cavity. Processes directed postero-laterally and slightly basally, at least one denticulate. Posterior process joins posterior margin, dinstinctively arched, sub-equal to cusp in length, first few denticles small, subsequent ones long and basally confluent. Denticles increase markedly in reclination posteriorly, longest denticles in mid-section of process, decreasing in size in both directions.

Basal cavity meets anterior margin at 120°, posterior process at 90°, outline diamond shaped but consisting of two v-shaped segments at 90° to each other, shallow and open to posterior; apex near to antero-basal corner.

Sb element

Similar to Sa element but with only a single lateral process. Process denticulate, arising from postero-lateral costa. Opposite face acostate or with low, sharp, narrow median costa; small, antero-laterally directed also may develop at base of costa.

Sc element

Cusp erect to reclined, anterior margin keeled and deflected inwards, posterior margin sharp, outer face broadly rounded, inner face distally convex, proximally flat. Posterior process straight or gently arched, much less so than on Sa and Sb elements, longest denticles anterior, decreasing in size and increasing in reclination posteriorly; up to seven denticles. Basal cavity narrow, curved through 90°, open to posterior, v-shaped anterior and posterior, inner face unexpanded, outer face broadly rounded and confluent with cusp.

M element

Cusp erect to reclined, anterior margin keeled, posterior margin sharp, outer face broadly rounded, inner face strongly convex, cusp deflected inwards. Posterior process short, straight, bearing up to five denticles, anteriormost is short, second is longest, others decrease in size but increase only slightly in reclination posteriorly.

Basal cavity broad and shallow, inner face strongly inflated, anterior v-shaped, extends posteriorly beneath posterior process as shallow trough.

Remarks: The apparatus structure is unusual for an apparatus containing denticulate ramiform elements since it has an M element and an Sa - Sc transition series but no P elements. The M element is distinguished from the Sc element by its incurved cusp, which is more strongly convex on the inner face, the expansion of the basal cavity on the inner face and the broader extension of the cavity under the posterior process. The posterior process is shorter and the denticles are more evenly reclined. A small number of intermediate M - Sc elements were found, as were intermediate morphologies between Sc and Sb (with faint costa and small alar) and Sb and Sa elements (with one process and one faint costa with small alar). The Sb element has been illustrated previously by Ethington and Clark (1982) as Erraticodon aff. E. balticus Dzik. Tipnis, Chatterton and Ludvigsen (1978) figured an Sb element which bears a lateral costa on the face opposite the process.

If the apparatus described above is complete, a new genus will need to be erected for this species. There are, however, two other possible relationships which must be considered. One is that these elements are part of the apparatus of Paraprioniodus costatus (Mound). The two suites of elements co-occur in most samples although "Cordylodus" sp. B does appear slightly lower in the Wandel Valley Formation in central Peary Land than P. costatus. If these elements do belong in P. costatus, they may be present as dimorphs of the Sa - Sc and M elements. The M elements are quite similar, but that of "C" sp. B differs in lacking an anticusp. I hesitate to combine the two apparatuses for three reasons; firstly, there is a slight discrepancy in the ranges, secondly, there are numerous occurrences of P. costatus elements without those of "*C.*" sp. B. and thirdly because to combine the two apparatuses would create an apparatus of very great, and previously undescribed, complexity.

The second possibility is that elements here described as *Erraticodon?* sp. A. constitute the P elements of the appratus. Elements of these morphologies were combined in the same apparatus (*Erraticodon* aff. *E. balticus*) by Ethington and Clark (1982). However, in Greenland, *E?* sp.A was found in only three samples in contrast to the relatively common occurrence of "*C.*" sp. B.

Range: From 118 m to 96 m below the top of the Wandel Valley Formation in central Peary Land and from 103 m to 80 m below the top in western Peary Land. From 36 - 258 m above the base of PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 11 Sa, 22 Sb, 54 Sc, 13 M.

cordylodiform 1

Pl. 3, Fig. 10

Remarks: A single unassignable cordylodiform element was recovered 20 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Genus CRISTODUS Repetski, 1982

1982 *Cristodus* Repetski, p. 18

Type Species: *Cristodus loxoides* Repetski, 1982

Remarks: The apparatus is bimembrate, with a geniculate "monodenticulate" element and a gently recurved "multidenticulate" element (terminology of Repetski, 1982); it probably corresponds to the Type III C apparatus of Barnes *et al.* (1979).

Cristodus loxoides Repetski, 1982

Pl. 3, Figs 11 - 13

1971 *Loxodus* sp. aff. *L. bransoni* Furnish; Barnes and Tuke, p. 87, pl. 20, Figs 1, 4, 15-17.

1980 New genus, new species; Grether and Clark, p. 14, pl. 1, Figs 44, 45.

1980 New genus B; Kennedy, p. 49, pl. 2, Figs 36, 37.

* 1982 *Cristodus loxoides* Repetski, p. 13-19, pl. 5, Figs 6, 7.

1982 Gen. nov. A sp. nov. A; Stouge, pl. 4, Figs 14, 15.

1983 *Loxodus?* sp. aff. *Loxodus bransoni* Furnish; Stouge, pl. 3, Figs 1, 2.

Remarks: The first description of the species is that of Barnes and Tuke (1971) and it has been recorded subsequently in open nomenclature. The illustrations of the monodenticulate element, together with

Repetski's (1982) description, indicate considerable variation in the length of the cusp and in the angle of the anterior edge relative to the base. The specimens from North Greenland correspond most closely to specimens from the El Paso Group (Repetski, 1982) and the St. Peter Sandstone (Grether and Clark, 1983). The multidenticulate elements compare exactly with Repetski's description.

Range: The species ranges from 20 m to 195 m in the Wandel Valley Formation in Kronprins Christian Land and was recorded from a sample 4 m up the same formation in Peary Land.

Number of Specimens: 4 monodenticulate, 4 multidenticulate.

Cristodus? sp. A

Pl. 3, Fig. 14

Remarks: A geniculate coniform broadly similar to the monodenticulate element of Cristodus loxoides Repetski, this differs in having a widely flared basal cavity open to the posterior. The tip of the cusp is albid.

Range: Found at 306 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 1 monodenticulate.

Genus CULUMBODINA Moskalenko, 1973

1973 Culumbodina Moskalenko, p. 64

Type Species: Culumbodina mangazeica Moskalenko, 1973

Culumbodina sp. A

Pl. 3, Figs 15-17

Remarks: A species of Culumbodina with a single, prominent notch in the posterior margin. The furrow on the outer face may be faint in some specimens and there is a prominent costa anterior to it which varies in position from just anterior to the furrow as far as the midline. The element is bowed inwards and the inner face is smooth; the anterior margin may be turned inwards.

The species is most similar to C. magna Moskalenko described from the Siberian Platform (Moskalenko, 1973). It differs in having a much narrower notch in the posterior margin and in being less prominently costate. Moskalenko (1982) has subsequently included C. magna as a junior synonoym of C. mangazeica.

Range: From 10 - 7 m below the top and in a sample 286 m above the base of the Wandel Valley Formation in central Peary Land. From 687 to 690 m above the base of PF 770713-1 on Albert Heim Bjerge and 60 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 13

Genus DAPSILODUS Cooper, 1976

1976 Dapsilodus Cooper, p. 211

Type Species: Distacodus obliquicostatus Branson and Mehl, 1933

Dapsilodus? nevadensis (Ethington and Schumacher, 1969)

Pl. 3, Fig. 18

1962 Oistodus? n. sp.; Sweet and Bergström, p. 1232-3, pl. 169, Figs 6, 7.

* 1969 Acontiodus nevadensis, Ethington and Schumacher, p. 450, 452, pl. 67, Figs 21, 22, text-Fig. 4C.

1969 Distacodus aff. D. bigdoeyensis Hamer (sic); Ethington and Schumacher, p. 460-1, pl. 68, Fig. 23, text-Fig. 4B.

1978 Protopanderodus cf. P. insculptus (Branson and Mehl); Tipnis, Chatterton and Ludvigsen, pl. 9, Fig. 6.

1982 Dapsilodus? nevadensis (Ethington and Schumacher); Ethington and Clark, p. 35, pl. 3, Fig. 1.

Remarks: The small collection at hand contains three element types. The most common is an erect to reclined bicostate element. The costae are sharp, narrow, posteriorly directed and situated just anterior to the sharp posterior margin. The upper edge of the base is produced as a heel and may bear a knob on the postero-basal corner. A second, common, element is recurved and smooth-sided, the junction between the posterior margin and the heel is sharply curved. A small number of similar specimens are less recurved, with a longer upper edge to the base and one flat and one convex lateral face.

The apparatus is assigned to Dapsilodus? on the basis of the morphology of the bicostate element and the presence in the apparatus of a non-geniculate r element. There are, however, significant differences between the apparatuses of D? nevadensis and the type species, D. obliquicostatus (Branson and Mehl). In particular, the r element in D. obliquicostatus differs in being robust, proclined and unicostate. The costae of the bicostate elements of Silurian species of Dapsilodus vary in position from the midline to near the posterior margin, a variation which has been interpreted as symmetry transition by Barrick (1977). The costae on the corresponding elements of D? nevadensis do not show this variation and are situated adjacent to the posterior margin, although collections are admittedly small.

The bicostate element of this species is also similar to one of the elements described as Paroistodus? mutatus (Branson and Mehl) by Nowlan (1981). The other elements of that apparatus are however of highly geniculate oistodiform and sharply costate acodiform morphology.

Aldridge (1982) described a fused cluster from western North Greenland and assigned it to a new genus, Besselodus. The apparatus of B. arcticus Aldridge contains bicostate elements similar to those of D? nevadensis but the other element in the cluster is again of highly geniculate oistodiform morphology.

Distacodus variabilis Webers, first described from Minnesota (Webers, 1966) is probably very closely related to D? nevadensis, having a very similar morphology and apparatus, but includes a squat, proclined element.

Range: From 288 m to 633 m above the base of PF 770713-1 and 93 m to 30 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak. It occurs in a single sample 33 m above the base of the new, un-named formation in Kronprins Christian Land.

Number of Specimens: 22 bicostate, 11 recurved, 3 scandodiform .

Genus *DIAPHORODUS* Kennedy, 1980

1980 *Diaphorodus* Kennedy, p. 51 - 52

Type Species: *Acodus delicatus* Branson and Mehl, 1933

Remarks: Kennedy (1980) erected *Diaphorodus* to include some species previously assigned to *Acodus*. He decided that until the apparatus of *A. erectus*, the type species, was reconstructed, it was preferable to regard *Acodus* as a *nomen dubium*. The apparatus is quinquimembrate and consists of a laterally costate P element, a geniculate coniform M element and a symmetry transition series of Sa, Sc and Sd elements. The elements are albid and adenticulate.

Diaphorodus delicatus (Branson and Mehl, 1933)

Pl. 4, Figs 1 - 5

*	1933	*Acodus delicatus*, Branson and Mehl, p. 56, pl. 4, Fig. 10
	1933	*Cordylodus simplex*, Branson and Mehl, p. 64, pl. 4, Fig. 11
	1933	*Paltodus distortus*, Branson and Mehl, p. 62, pl. 4, Fig. 22
	1933	*Oistodus expansus*, Branson and Mehl. p. 60, 109, pl. 4, Fig. 4.
	1933	*Oistodus vulgaris*, Branson and Mehl, p. 60-61, pl. 4, Fig. 5
	1973	*Acodus deltatus deltatus* Lindström; McTavish, p. 39-40, pl. 1, Figs 1-9, 12-14, text-Figs 3 p-t.
p	1977	*Acodus brevis* Branson and Mehl; Lindström *in* Klapper *et al.*, p. 5-6, Acodus pl. 2, Figs 2, 3, 4 only.

1980 Diaphorodus delicatus (Branson and Mehl); Kennedy, p. 52-54, pl. 1, Figs 3-7, 9-25 (synonomy to 1978)

1982 Acodus delicatus Branson and Mehl; Repetski, p. 10-11, pl. 1, Figs 5a-9c

? 1982 Acodus? sp. cf. A. delicatus Branson and Mehl; Stouge, p. 34, pl. 4, Figs 1, 2, 5.

Remarks: The apparatus was reconstructed and thoroughly described by Kennedy (1980) and, with the relatively small amount of material at hand, little can be added to his description. Many of the elements, especially M, Sa and Sc, have morphologies which are common to several species and can only be assigned in the presence of the more diagnostic P elements.

Range: From 35 m to 155 m in the Wandel Valley Formation in Kronprins Christian Land. From 830 m to 1086 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 40 P, 41 M, 6 Sa, 23 Sc, 13 Sd.

Diaphorodus? russoi (Serpagli, 1974)

Pl. 4, Figs 6, 7

* 1974 Acodus? russoi, Serpagli, p. 35-37, pl. 8, Figs 1-5, Pl. 20, Figs 7, 8, text-Fig. 5, (synonomy to 1970)

1980 Acodus? russoi, Serpagli, p. 13, pl. 3, Figs 1a-5c.

Remarks: Specimen from the upper Cape Weber Formation are morphologically very similar to those described by Serpagli (1979) and Repetski (1978) as A? russoi. Insufficient material is available to fully reconstruct the apparatus, but Repetski (1982) included five elements.

Lindström (1977) considered the apparatus to be referable to Oistodus Pander without giving reasons. The quinquimembrate apparatus is incompatible with inclusion in Oistodus but if the belodiform element does occupy the P position, as suggested by Repetski (1982), it is comparable with species of Diaphorodus. A drawback to this hypothesis is the lack of a typical Sc element although the "oepikodiform" element of Serpagli (1974) and Repetski (1982) may occupy the Sc position. For the present, the generic affinity must remain in doubt.

Range: From 976 m to 992 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 5 M, 2 Sa, 1 ?Sc, 1 Sd.

Diaphorodus sp. nov. A

Pl. 4, Figs 8 - 12

Remarks: This distinctive species has an apparatus which fits exactly the generic diagnosis of Diaphorodus given by Kennedy (1980), the elements being albid, adentate and with poorly developed keels. The apparatus contains a pastinate P element, a geniculate coniform M element and a transition series of Sa, Sc and Sd elements. The elements are characteristic in having extremely long processes.

Of previously described species, Diaphorodus sp. nov. A. most closely resembles D. longibasis McTavish but differs in having all the processes sub-equal in length instead of only an extended posterior process. It is distinguished from Diaphorodus? emanuelensis, in having much longer processes on all elements and a P element that is pastinate.

Range: At 20 m up the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 15 P, 29 M, 2 Sa, 11 Sc, 14 Sd

Diaphorodus? sp. B.

Pl. 4, Figs 13 - 17

1982 Acodus? aff. A. emanuelensis McTavish; Ethington and Clark, p. 19-20, pl. 1, Figs 9-13, text-Fig. 5.

Remarks: Ethington and Clark (1982) described a plexus of elements which they tentatively assigned to D? emanuelensis (McTavish). They commented that the apparatus shows a total intergradation of element types, rendering grouping of morphologies very difficult. The same is true of the small number of specimens from Greenland. Only a few features are present in all element types; the rudimentary denticles mentioned by Ethington and Clark (1982) are common, as is a nick at the junction between the cusp and the upper edge of the base. The Sa element is similar to, but narrower than, the Sa element of D. delicatus.

Range: From 848 m to 992 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 17 P, 17 M, 65 Sa, 20 Sc, 4 Sd.

Genus DREPANODUS Pander, 1856

1856 Drepanodus Pander, p. 20

Type Species: Drepanodus arcuatus Pander, 1856

Drepanodus arcuatus Pander, 1856

Pl. 4, Figs 18 - 20

* 1856 Drepanodus arcuatus Pander, p. 20, pl. 1, Figs 2, 4, 5, 17, ? pl. 1, Figs 30, 31

1856 Drepanodus flexuosus Pander, p. 20, pl. 1, Figs 6-8

1955 Acontiodus arcuatus Lindström, p. 547, pl. 2, Figs 1-4, text-Fig. 3A

1955 Drepanodus arcuatus, Pander; Lindström, p. 558-60, pl. 2, Figs 30-33, text-Fig. 3J

1955 Drepanodus cf. arcuatus Pander; Lindström, p. 560-61, pl. 2, Figs 45, 46, text-Fig. 4C

1955 Drepanodus? gracilis (Branson and Mehl); Lindström, p. 562-63, pl. 4, Fig. 44, pl. 5, Figs 6, 7

1955 Drepanodus sculponea, Lindström, p. 567, pl. 2, Fig. 40, text-Fig. 3L

1955 Scandodus pipa, Lindström, p. 593, pl. 4, Figs 38-42, text-Fig. 3P

1971 Drepanodus arcuatus Pander; Lindström, p. 41, Figs 4, 8

1974 Drepanodus arcuatus Pander; van Wamel, p. 61-62, pl. 1, Figs 10-13

1978 Drepanodus arcuatus Pander; Löfgren, p. 51-53, pl. 2, Figs 1-8, (synonomy to 1977)

1978 Drepanodus arcuatus Pander; Tipnis, Chatterton and Ludvigsen, pl. 2, Figs 1-3

1979 Drepanodus arcuatus Pander; Bednarczyk, p. 424, pl. 5, Figs 14-6, pl. 6, Figs 4, 10, 11, 13

1982 ?Drepanodus arcuatus Pander; Ethington and Clark, p. 36-37, pl. 3, Figs 4-6, 12

1982 Drepanodus arcuatus Pander; Repetski, p.19-20, pl. 6, Fig. 1

1982 ?Drepanodus cf. D. arcuatus Lindström (sic); Repetski, p.20, pl. 6, Fig. 4, text-Fig. 4Q

1982 Drepanodus? gracilis (Branson and Mehl); Repetski, p. 20, pl. 6, Fig. 6, text-Fig. 45

1982 Drepanodus sculponea Lindström; Repetski, p. 22, pl. 7, Fig. 9

1982 Scandolus cf. S. pipa Lindström; Repetski, p. 44, pl. 20, Fig. 5, text-Fig. 7G

1982 Drepanodus arcuatus Pander; Stouge, pl. 5, Figs 18-19

1983 Drepanodus? arcuatus Pander; Stouge, pl. 4, Figs 1, 2

non 1983 Drepanodus arcuatus Pander, Ni in Zeng et al., pl. 10, Figs 33, 35

Remarks: The apparatus of D. arcuatus was first reconstructed by Lindström (1971) who included two elements, drepanodiform and oistodiform. A more complex apparatus plan was proposed by van Wamel (1974) and supported by Löfgren (1978). In van Wamel's interpretation, the apparatus is quadrimembrate and composed of elements termed arcuatiform, sculponeaform, pipaform and graciliform, although Löfgren considered the first two to be variants of the drepanodiform and the last two to be oistodiform variants. A further variant within the apparatus is a postero-laterally costate arcuatiform element (Löfgren, 1978).

The Greenland specimens conform to previous descriptions but some elements, particularly arcuatiform specimens, can be difficult to distinguish from those of D. concavus (Branson and Mehl). In such cases the distribution of white matter has been used to distinguish between species although this is a somewhat variable character (Kennedy, 1980) and some specimens of D. concavus morphology are albid. Arcuatiform elements of D. arcuatus tend to have a less flared base and are generally smaller than those of D. concavus. Sculponeaform elements are closely similar to those of D. concavus but pipaform and graciliform elements are quite characteristic and offer a more secure means for distinguishing the two species.

No costate arcuatiforms were recovered from Greenland, a feature also noted in Utah (Ethington and Clark, 1982) and Argentina (Serpagli, 1974). This was tentatively explained as being due to the presence of a separate sub-species in these areas by Löfgren (1978). Further work is needed to clarify the relationship of Midcontinent Province D. arcuatus to North Atlantic Province D. arcuatus although, for the present, they are considered to be conspecific.

Range: From 10 m to 200 m in the Wandel Valley Formation in Kronprins Christian Land and from 164 m to 1390 m in section PF 770824-1 on Ella Ø.

Number of Specimens: 49 arcuatiform, 30 sculphoneaform, 41 pipaform.

Drepanodus concavus (Branson and Mehl, 1933)

Pl. 5, Figs 1 - 10

* 1933 Oistodus concavus Brnason and Mehl, p. 59, pl. 4, Fig. 6

1933 Oistodus gracilis Branson and Mehl, p. 60, pl. 4, Fig. 20

1933 Oistodus pandus Branson and Mehl, p. 61, 110-11, pl. 4, Figs 21, 22

1980 Drepanodus concavus (Branson and Mehl); Kennedy, p. 55-57, pl. 1, Figs 26-34, (synonomy to 1975)

1982 Drepanodus sp. 1; Ethington and Clark, p. 40, pl. 3, Fig. 13, text-Fig. 11

1982 Drepanodus? sp. 2, Ethington and Clark, p. 40-41, pl. 3, Fig. 14, text-Fig. 12

1982 Drepanodus concavus (Branson and Mehl); Repetski, p. 20, pl. 6, Fig. 11, text-Fig. 4R

1982 Drepanodus pandus (Branson and Mehl); Repetski, p. 20, pl. 6, Fig. 7

1982 Oistodus gracilis Branson and Mehl; Repetski, p. 32, pl. 9, Fig. 10

1982 Drepanodus? gracilis (Branson and Mehl); Stouge, p. 34, pl. 3, Figs 2, 3

1982 "Oistodus concavus" Branson and Mehl; Stouge, p. 35, pl. 2, Fig. 23

1982 Drepanodus pandus (Branson and Mehl); Moskalenko, p. 109, pl. 26, Fig. 8

1983 Drepanodus? gracilis (Branson and Mehl); Stouge, pl. 2, Figs 6, 7

1983 Drepanodus arcuatus Pander; Ni in Zeng et al., pl. 10, Fig. 35, ?Fig. 33.

Remarks: The elements included here were given separate names until Kennedy (1980) grouped them together as a species of Drepanodus. As first revisor Kennedy chose D. concavus from the three available names used by Branson and Mehl (1933). The morphology of the component elements is very close to that of D. arcuatus but Kennedy cited the major differences as being the hyaline nature, the large size of elements and the profile of the arcuatiform of D. concavus. The identification of specimens from Greenland has rested largely on their albid or hyaline nature. This may, however, prove untenable since some of the albid arcuatiform elements seem to have the pinched antero-basal corner characteristic of D. concavus.

Other differences occur in the oistodiform elements (sensu Löfgren, 1978). In D. arcuatus the pipaform elements are common but graciliform rare with a ratio of approximately 5.5:1. The situation is reversed in D. concavus, with those elements interpreted as pipaform by

Kennedy (1980) being the rarest components of the apparatus. These elements are highly characteristic with a basal margin turned through 110° and a lip on the anterior part of the basal margin (Kennedy, 1980, pl. 1, Fig. 31; Abaimova, 1975, pl. 4, Fig. 11). In addition, the basal asymmetry of the graciliform element of D. arcuatus noted by Lindström (1955) is not seen in the graciliform of D. concavus and the cusp-base junction is acute in the latter species. The pipaform and graciliform elements of D. arcuatus and D. concavus may not be fully homologous and it is possible that the "graciliform" of D. concavus (sensu Kennedy, 1980) is homologous with the pipaform of D. arcuatus rather than with the graciliform.

Kennedy (1980) noted that transitional specimens between arcuatiform and sculponeaform elements occur. This is also the case in Greenland, where relatively few specimens corresponding closely to Kennedy's figures have been found, the majority of arcuatiform elements being more similar to those figured by Abaimova (1975, pl. 4, Figs 3 - 5). The specimens described herein as Drepanodus sp. C are closely similar to arcuatiform elements of D. concavus except for the presence of an antero-laterally directed antero-lateral costa. These elements may prove to be the equivalent element in D. concavus to those of the form taxon Acontiodus arcuatus Lindström included in the apparatus of D. arcuatus by van Wamel (1974) and Löfgren (1978).

Range: D. concavus occurs from the base of the Wandel Valley Formation up to 147 m in central Peary Land and up to 200 m in Kronprins Christian Land. The species has a range from 134 to 1086 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 189 arcuatiform, 49 sculponeaform, 82 graciliform, 17 pipaform.

Drepanodus costatus Abaimova, 1971

Pl. 5, Fig. 11

* 1971 Drepanodus costatus Abaimova, p. 77-78, pl. 10, Fig. 6, text-Fig. 3

1975 Drepanodus costatus Abaimova; Abaimova, p. 59-60, pl. 3 Figs 6-8, text-Figs 6, 25, 28, 29

1982 Drepanodus costatus Abaimova; Moskalenko, p. 109, pl. 27, Figs 1-3

Remarks: The specimens have costae which are most pronounced in the posterior part of the cusp at the point of greatest recurvature, although one or more of the costae may run sub-parallel to the posterior margin until near the cusp tip. The specimens illustrated by Moskalenko (1982) are more prominently costate than those from Greenland and those figured by Abaimova (1971, 1975).

In the absence of large collection , it is difficult to decide whether D? costatus represents a poorly known species of Drepanodus or is a unimembrate apparatus, possibly referable to Eucharodus.

Range: From 4 m to 9 m in the Wandel Valley Formation in central Peary Land and at 404 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 3

"Drepanodus" sp. A

Pl. 5, Fig. 12

Remarks: A slender reclined coniform element of biconvex cusp cross-section. Albid above the basal cavity, which is deep and straight-sided.

Range: Found at 15 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 2

Drepanodus? sp. B

Pl. 5, Fig. 13

Remarks: Cusp rounded in cross-section, reclined. Posterior and anterior margins are straight. The base is widely flared and very shallow; unequally developed laterally with a faint ridge running antero-laterally. Hyaline except for a thin growth axis; surface smooth.

Range: Found at 562 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 1

Drepanodus sp. C

pl. 5, Figs 14, 15

1982 "Scolopodus" inconstans Branson and Mehl; Stouge, p. 35, pl. 2, Fig. 24

Remarks: The element is close in overall morphology to the arcuatiform element of Drepanodus concavus but has a sharp, antero-lateral costa on the less-expanded inner face. The costa is present only on the base, starting near the anterior margin and diverging basally, and is directed antero-laterally. A second, sharp costa may be present on the outer face, very close to, and parallel with, the anterior margin. In such elements, there is a v-shaped groove between the costae.

Costate arcuatiform elements are known to occur in the apparatus of D. arcuatus (van Wamel, 1974; Löfgren, 1978) but have not been described in the apparatus of D. concavus (Kennedy, 1980). The costate arcuatiform elements of D. arcuatus (Acontiodus arcuatus Lindström, 1955) have the costae situated adjacent to the posterior margin and running the full length of the cusp. Drepanodus sp. C may be a homologous element in the D. concavus apparatus but larger collections are needed to ascertain whether this is definitely the case.

Range: From 35 m to 167 m in the Wandel Valley Formation in Kronprins Christian Land and in a single sample at 30 m in Børglum Elv.

Number of Specimens: 7

Genus DREPANOISTODUS Lindström, 1971

1971 Drepanoistodus Lindström, p. 42

Type Species: Oistodus forceps Lindström, 1955

Drepanoistodus angulensis (Harris, 1962)

Pl. 6, Figs 1 - 4

*	1962	Oistodus angulensis, Harris, p. 199-201, pl. 1, Figs 1a-c
	1982	Drepanoistodus angulensis (Harris); Ethington and Clark, p. 41-42, pl. 3, Figs 18-21 (synonomy to 1973)
?	1982	?Drepanoistodus angulensis (Harris); Ethington and Clark, p. 42, pl. 3, Figs 16, 17

Remarks: The apparatus was first reconstructed by Ethington and Clark (1982) who recognised a deviation from the standard trimembrate apparatus structure of Drepanoistodus in the development of a variant on the q element which they termed scandodiform, here termed q_2 . This element differs from the normal q element in lacking a compressed antero-basal corner. All four element types are well-represented in the Greenland fauna.

The q_1, q_2 and r elements of D. angulensis are similar to the arcuatiform, pipaform and graciliform elements of Drepanodus concavus but the apparatus is distinguished by the presence of the p element and the lack of a sculponeaform.

Ethington and Clark (1982) mentioned the difficulty in distinguishing between D. angulensis and D. suberectus toward the top of the range of D. angulensis and for this reason assigned some of their intermediate specimens to ?D. angulensis. The p and q_1 element of the two species are almost identical and only the r elements are diagnostic. However, r elements of intermediate morphology were found in Greenland towards the top of the range of D. angulensis but co-occurred with more typical D. angulensis r elements. No unequivocal specimens of D. suberectus were found in my collections from North Greenland.

Range: From 168 m above the base to 7 m below the top of the Wandel Valley Formation in central Peary Land and 260 m above the base of the Wandel Valley Formation to 33 m up the new, un-named formation in Kronprins Christian Land.

Number of Specimens: 6 p, 47 q_1, 9 q_2, 14 r.

Drepanoistodus aff. D. forceps (Lindström, 1955)

Pl. 6, Figs 5 - 7

?* 1955 Oistodus forceps, Lindström, p. 574, pl. 4, Fig. 9-13, text-Fig. 3M

1965 Oistodus forceps, Lindström; Ethington and Clark, p. 194-5, pl. 1, Fig. 18

? 1971 Drepanoistodus forceps (Lindström); Lindström, p. 42-43, text-Figs 5, 8

1971 Drepanoistodus forceps (Lindström); Ethington and Clark, p. 76, pl. 2, Fig. 8

? 1978 Drepanoistodus forceps (Lindström); Fahraeus and Nowlan, p. 459, pl. 1, Figs 22-25

? 1978 Drepanoistodus forceps (Lindström); Löfgren, p. 53-4, pl. 1, Figs 1-6

1982 Drepanoistodus aff. D. forceps (Lindström); Ethington and Clark, p. 43, pl. 3, Figs 22-24, text-Fig. 13

Remarks: Ethington and Clark (1982) considered specimens of Drepanoistodus from Utah, Nevada (Ethington and Clark, 1971) and Alberta (Ethington and Clark, 1965) to be closely related to D. forceps but possibly not conspecific with it. The specimens from Ella Ø closely resemble theirs in having a less acute, more rounded antero-basal corner than is normal in Baltic collections of D. forceps (Lindström, 1955, Löfgren, 1978).

Range: From 848 m to 992 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 2 p, 17 q, 11 r.

Drepanoistodus suberectus (Branson and Mehl, 1933)

Pl. 6, Figs 8 - 10

? 1930 Distacodus arcuatus, Stauffer, p. 123, pl. 10, Fig. 2

* 1933 Oistodus suberectus, Branson and Mehl, p. 111, pl. 9, Fig. 7

	1933	Oistodus curvatus, Branson and Mehl, p. 110, pl. 9, Figs 4, 10, 12
	1933	Oistodus inclinatus, Branson and Mehl, p. 110, pl. 9, Fig. 8
?	1935a	Oistodus brevis, Stauffer, p. 609, pl. 74, Fig. 32
?	1935a	Oistodus erectus, Stauffer, p. 609-10, pl. 74, Fig. 50
	1935a	Oistodus excelsus, Stauffer, p. 610, pl. 74, Fig. 43
	1935a	Oistodus giganteus, Stauffer, p. 610, pl. 74, Fig. 45
	1955	Drepanodus homocurvatus, Lindström, p. 503, pl. 2, Figs 23, 24, 39, text-Fig. 4d
	1966	Drepanodus suberectus (Branson and Mehl); Webers, p. 29-30, pl. 6, Figs 9, 11, 14, 16
	1966	Drepanodus suberectus (Branson and Mehl): Bergström and Sweet, p. 330-3, pl. 35, Figs 22-27, (synonomy to 1966)
	1974	Drepanoistodus suberectus (Branson and Mehl); Uyeno, p. 14, pl. 1, Figs 5-9, (synonomy to 1973)
	1978	Drepanoistodus suberectus (Branson and Mehl); Tipnis, Chatterton and Ludvigsen, pl. 7, Figs 25-27
	1979	Drepanoistodus suberectus (Branson and Mehl); Sweet, pl. 7, Figs 21, 23, 30
	1979	Drepanoistodus suberectus (Branson and Mehl); Bolton and Nowlan, p. 18, pl. 7, Figs 11, 15, 16
	1980	Drepanoistodus suberectus (Branson and Mehl); Orchard, p. 23, pl. 5, Figs 10, 11, 26, 27, 31

1981 Drepanoistodus suberectus (Branson and Mehl); McCracken and Barnes, p. 77, pl. 3, Figs 1-6, (synonomy to 1981)

1982 Drepanoistodus suberectus (Branson and Mehl); Lenz and McCracken, pl. 2, Fig.22

1982 Drepanoistodus suberectus (Branson and Mehl); Sweet, pl. 1, Figs 7, 8, 11, 18, 19

1983 Drepanoistodus suberectus (Branson and Mehl); Nowlan, pl. 3, Figs 22, 23

Remarks: D. suberectus is one of the most common Ordovician conodont species, and the apparatus is now well known (Bergström and Sweet, 1966; Nowlan and Barnes , 1981). The species occurs in low abundance through most of the Heim Bjerge Formation of East Greenland but was not recovered from the Wandel Valley Formation. Nowlan and Barnes (1981) noted that three types of white matter distribution can occur, often in the same sample. The amount of white matter varies from being present as a growth axis to cloudy throughout the cusp to totally albid. All stages of this series were found in the Greenland collection and, as noted by Nowlan and Barnes (1981), the hyaline forms tend to be larger than albid forms.

A cluster consisting of four D. suberectus of elements was recovered from the Heim Bjerge Formation and is described in Chapter 7.

Range: From 194 m above the base to the top of PF 770713-1 and at 90 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 1 p, 19 q, 4 r

?*Drepanoistodus suberectus* (Branson and Mehl, 1933)

Pl. 6, Figs 11, 12

?* 1933 *Oistodus suberectus*, Branson and Mehl, p. 111, pl. 9, Fig. 7

? 1933 *Oistodus erectus*, Branson and Mehl, p. 110, pl. 9, Figs 4, 10, 12

1970 *Drepanodus homocurvatus* Lindström; Lee, p. 320-2, pl. 7, Figs 16, 17

1970 *Drepanodus suberectus* (Branson and Mehl); Lee, p. 322-323, pl. 7, Fig. 16

1971 *Drepanodus homocurvatus* Lindström; Greggs and Bond, p. 1465, pl. 1, Figs 6, 7

1971 *Drepanodus homocurvatus* Lindström; Ethington and Clark, pl. 1, Fig. 1

1971 *Drepanodus suberectus* (Branson and Mehl); Ethington and Clark, pl. 1, Fig. 7

? 1975 *Drepanodus homocurvatus* Lindström; Lee, p. 85, pl. 2, Fig. 1, text-Fig. 4A

1975 *Drepanodus suberectus* (Branson and Mehl); Lee, p. 86-7, pl. 2, Fig. 8, text-Fig. 4F

1975 *Drepanodus homocurvatus* Lindström; Abaimova, p. 61-2, pl. 5, Figs 1-5, text-Figs 6, 22, 23

1975 *Drepanodus suberectus* (Branson and Mehl); Abaimova, p. 68-9, pl. 5, Figs 10-12, text-Fig. 7. 2, 7, 8

1975 Drepanodus suberectus (Branson and Mehl); Cooper and Druce, p. 573, pl. 1, Fig. 20.

1982 Drepanodus suberectus subsp. A. (Branson and Mehl); Repetski, p. 25, pl. 7, Fig. 13, pl. 8, Fig. 5.

Remarks: Clark (1972) proposed that the apparatus of D. suberectus lacked an oistiodiform inthe Lower and early Middle Ordovician, consisting simply of p and q elements. Repetski (1982) chose to retain Lower Ordovician representatures in D. suberectus but placed them in an un-named subspecies. It is unlikely that these elements can remain in D. suberectus since even if there is a close relationship, as suggested by Clark, the lack of an r element is probably sufficient to warrant placement in a separate species.

The q elements of ?D. suberectus are very similar in morphology to the arcuatiform element of Drepanodus concavus and are distinguished by the presence of white matter. Since the presence or absence of white matter is variable, and its taxonomic significance in this group debatable (Kennedy, 1980), this is not a totally reliable character and some of the more hyaline specimens of ?D. suberectus may have been included in D. concavus, the opposite may also be true.

The p element differs from that of D. suberectus in being less drawn out antero-basally and having a basal cavity that is more widely flared posteriorly. The q element differs in commonly having an anterior margin which is deflected inwards, flanked posteriorly by a shallow groove.

Range: Up to 30 m in the Wandel Valley Formation in central Peary Land and from 35 m to 200 m in the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 24 p, 25 q.

Drepanoistodus sp. A.

Pl. 6, Fig. 13

?p 1982 Oistodus aff. forceps Lindström; Moskalenko, p. 123-4, pl. 26, Fig. 10 only (non Figs. 11, 12)

Remarks: Only the r element of this species was recovered but is very distinctive due to its small size. The element has a long base, a convex basal margin and is acostate.

Range: From 20 to 200 m in the Wandel Valley Formation in Kronprins Christian Land and at 868 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 10

Genus ERISMODUS Branson and Mehl, 1933

1933 Erismodus Branson and Mehl, p. 25

1933 Microcoelodus Branson and Mehl, p. 89

1955 Ptiloconus Sweet (nom. subst. pro. Pteroconus, Branson and Mehl, 1933) p. 245

1970 Multocornis Moskalenko, p. 74

Type Species: Erismodus typus Branson and Mehl, 1933

Erismodus asymmetricus (Branson and Mehl)

Pl. 6, Figs 14, 15

1933 Microcoelodus alatus, Branson and Mehl, p. 90, pl. 6, Figs 31, 32

* 1933 Microcoelodus asymmetricus, Branson and Mehl, p. 91, pl. 7, Figs 5, 10, 11, 14, 15

1933 Microcoelodus brevibrachiatus, Branson and Mehl, p. 91-92, pl. 7, Figs 3, 27

1933 Microcoelodus breviconus, Branson and Mehl, p. 93, pl. 6, Fig. 29

1933 Microcoelodus duodentatus, Branson and Mehl, p. 92, pl. 7, Fig. 7

? 1933 Microcoelodus expansus, Branson and Mehl, p. 93, pl. 6, Fig. 7

1933 Microcoelodus magnicornis, Branson and Mehl, p. 93-94, pl. 7, Figs 13, 17

1933 Microcoelodus magnidentatus, Branson and Mehl, p. 94, pl. 7, Figs 8, 9

1933 Microcoelodus simplex, Branson and Mehl, p. 94-95, pl. 6, Fig. 30, pl. 7, Fig. 23

1933 Microcoelodus symmetricus, Branson and Mehl, p. 95, pl. 7, Fig. 21

1933 Microcoelodus typus, Branson and Mehl, p. 90, pl. 6, Figs 31, 32

1933 Microcoelodus unibrachiatus, Branson and Mehl, p. 95, pl. 6, Fig. 23

1933 Microcoelodus unicornis, Branson and Mehl, p. 96, pl. 6

1933 Microcoelodus unilateralis, Branson and Mehl, p. 96, pl. 7, Fig. 4

1964 Microcoelodus typus, Branson and Mehl; Lindström, p. 145, text-Fig. 50a

1967 Erismodus asymmetricus (Branson and Mehl); Andrews, p. 893-4, pl. 112, Figs 1, 3, 6, 7, 14, 17, pl. 113, Fig. 1, pl. 114, Figs 7, 9, 13

1967 Erismodus ?expansus (Branson and Mehl); Andrews, p. 395, pl. 114, Figs 16, 23

1967 Erismodus gracilis (Branson and Mehl); Andrews, p. 894-5, pl. 112, Fig. 9

1967 Erismodus symmetricus (Branson and Mehl); Andrews, p. 892-3, pl. 112, Figs 4, 5, 13, 16, 21, pl. 113, Fig. 7, pl. 114, Figs 4, 18, 24

1982 *Erismodus asymmetricus* (Branson and Mehl); Ethington and Clark, p. 44-5, pl. 4, Figs 19-22, (synonomy to 1967)

Remarks: The taxonomy of *Erismodus* and *E. asymmetricus* was thoroughly reviewed by Ethington and Clark (1962). The Greenland specimens are poorly preserved but comply with Ethington and Clark's (1982) concept of *E. asymmetricus*, comprising a symmetrical to asymmetrical transition series.

Range: From 81 to 3 m below the top of the Wandel Valley Formation in central Peary Land. It occurs from 6 m to 75 m of the new, un-named formation in Kronprins Christian Land.

Number of Specimens: 4 asymmetrical, 2 symmetrical.

Genus ERRATICODON Dzik, 1978

1978 Erraticodon Dzik, p. 64

Type Species: Erraticodon balticus Dzik, 1978

Erraticodon balticus Dzik, 1978

Pl. 6, Figs 16 - 21

p 1962 "Cordylodus" sp.; Sweet and Bergström, p. 1250, pl. 169, Fig. 16 only (non Fig. 1)

1962 "Eoligonodina" sp.; Sweet and Bergstrom, p. 1250, pl. 169, Fig. 5

1962 "Tvaerenognathus" sp.; Sweet and Bergström, p. 1250, pl. 169, Fig. 13

1962 Ptiloconus gracilis (Branson and Mehl); Sweet and Bergström, p. 1250, pl. 169, Fig. 15

1966 Phragmodus? n.sp.; Fahraeus, p. 28, pl. 3, Figs 12 a, b

1966 "Fibrous" conodonts; Fahraeus, p. 32, pl. 4, Figs 6-86

1969 "Cyrtoniodus" sp.; Ethington and Schumacher, p. 479-80, pl. 67, Fig. 10

1969 "Eoligonodina" sp.; Ethington and Schumacher, p. 480-1, pl. 68, Fig. 17

1974 "Chirognathus" sp.; Viira, p. 63, pl. 11, Figs 15, 21, 22

? 1977 "Cyrtoniodus" sp.; Ethington and Schumacher; Lee, p. 131, pl. 2, Figs 1, 2

? 1977 Oepikodus? sp.; Lee, p. 135-6, pl. 2, Fig. 13

? 1977 Erismodus horridus Harris; Barnes, p. 103, pl. 2, Fig. 8

* 1978 Erraticodon balticus, Dzik, p. 66, pl. 15, Figs 1-3, 5, 6, text-Fig. 3

1979 Erraticodon sp.; Harris et al., pl. 3, Figs 1-5

p 1982 Erraticodon aff. E. balticus Dzik; Ethington and Clark, p. 45, pl. 4, Figs 15, 23 only (non Figs 17, 24)

? 1982 Erraticodon? sp.; Ethington and Clark, p. 45-6, pl. 4, Fig. 18

1983 ?Erraticodon balticus Dzik; Stouge, pl. 5, Figs 9-12

Remarks: The apparatus of E. balticus described by Dzik (1978) comprises Pa (spathognathiform of Dzik(1978)) Pb (ozarkodiniform), M (neoprioniodiform), Sa (trichonodelliform), Sb (plectospathodiform) and Sc (hindeodelliform) elements. This reconstruction was based on material recovered from erratic blocks in Poland but of Baltic provenance. The species has been previously illustrated from Sweden (Fahraeus, 1966) and Estonia (Viira, 1974).

The elements of the apparatus have also been figured several times from the Midcontinent Province, often tentatively assigned to pre-existing form genera (Sweet and Bergström, 1962; Ethington and Schumacher, 1969). The conspecifity of Baltic and Midcontinent Erraticodon was considered to be uncertain by Ethington and Clark (1982), since their material lacked any P elements and had an Sc element of very different morphology from that figured by Dzik (1978).

However, I consider the elements in the apparatus reconstructed by Ethington and Clark (1982) to belong to several apparatuses. The neoprioniodiform and trichonodelliform elements illustrated by Ethington and Clark (1982, pl. 4, Figs 15, 23) came from samples containing _Phragmodus_ _flexuosus_ Moskalenko, but the hindeodelliform and plectospathodiform elements (pl. 4, Figs 17, 24) are older and occur with _Paraprioniodus_ _costatus_ (Mound). I would not include the latter two elements in _E. balticus_. The hindeodelliform element is comparable with the Sb elements here included in _"Cordylodus"_ sp. B and the plectospathodiform element, which is more massive and has more peg-like denticles than that in _E. balticus_, is included in _Erraticodon?_ sp. A. The element illustrated by Ethington and Clark (1982) as _?Erraticodon_ sp. may be a Pa element of _E. balticus_ with a single anterior denticle.

The collection of elements from Greenland is small but all except the Pa were recovered. The elements are closely similar to those figured by Dzik (1978), but the Sc element has a cusp which is much smaller than the largest denticle, being similar to that figured by Stouge (1983, pl. 5, Fig. 12).

Range: From 81 m to 10 m below the top of the Wandel Valley Formation in central Peary Land and at 33 m up the new, un-named formation in Kronprins Christian Land. From 278 to 690 m in PF 770713-1 on Albert Heim Bjerge and 90 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 4 Pb, 2 M, 4 Sa, 3 Sb, 3 Sc.

Erraticodon? sp. A

Pl. 6, Figs 22 - 23

? 1978 *Erismodus* sp. A; Tipnis, Chatterton and Ludvisgen, pl. 4, Figs 23, 24

p 1982 *Erraticodon* aff. *E. balticus* Dzik; Ethington and Clark, p. 45, pl. 4, Fig. 24 only, (non Figs 15, 17, 23)

Description:

Pastinate element

Cusp slender, circular cross-section, finely tapering. Anterior and posterior processes form a bar, bowed inwards. Cusp and denticles all strongly inclined inwards. Denticles long, slender, up to four on posterior process, second and third the longest, first and fourth very short; two to three on anterior process, third very short if present, longest denticles three-quarters height of cusp. Lateral process bears up to three denticles of less than one-quarter cusp height, angled down at 60° to horizontal, approximately as a continuation of the cusp.

Basal cavity shallow, apex below cusp, extends beneath all processes as narrow, tapering trough.

Tertiopedate element

Cusp of strongly biconvex cross-section, straight, anterior and posterior margins sharp, recurved almost parallel to posterior process. Posterior process subtends angle of 80° with shorter lateral process, bears up to two denticles sub-parallel to cusp. Lateral processes directed slightly anteriorly, shorter bears up to four denticles but usually two, longer bears three to four denticles. Denticles less reclined than cusp, circular in cross-section, those on longer process half to three-quarters cusp height, those on shorter less than half.

Basal cavity broad, shallow, extends as shallow trough to ends of processes.

Remarks: The tertiopedate element has previously been figured as an element of E.aff. balticus by Ethington and Clark (1982) but differs from E. balticus in having fewer more discrete denticles of circular cross-section. The specimen figured as Erismodus sp. A by Tipnis, Chatterton and Ludvigsen (1978) is similar to the tertiopedate element but has more denticles on the posterior process.

The tertiopedate element seems to occur in association, and have a similar overall morphology to, the pastinate element and the two are interpreted as being part of the same apparatus. The tertiopedate element has a morphology similar to that seen in E. balticus and the pastinate element is similar to the Pa of E. patu Cooper. The elements may thus be part of the apparatus of a previously undescribed species of Erraticodon. If this is the case, a problem arises as to which elements complete the apparatus. The only elements in the Greenland collections which could be added are those described as "Cordylodus" sp. B. The association in samples is, however, inconsistent and the morphologies of the two sets of elements are rather different as regards denticle shape and morphology. In addition, such an apparatus would have both modified bipennate and tertiopedate Sb elements. On balance, I consider it preferable to keep the two apparatuses distinct. Other elements of E? sp. A may yet be found in larger collections.

Range: 221 m and 239 m above the base and 118 m and 107 m below the top of the Wandel Valley Formation in central Peary Land. From 124 to 168 m in PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 9 pastinate, 5 tertiopedate.

Genus EUCHARODUS Kennedy, 1980

1980 Eucharodus Kennedy, p. 57

Type Species: Drepanodus parallelus Branson and Mehl, 1933

Eucharodus apion sp.nov.

Pl. 7, Figs 1 - 3

Derivation of Name: apion (Gr.), pear, with reference to the basal outline.

Diagnosis: A hyaline coniform element with a proclined to erect cusp, strongly deflected to the inner side and a characteristic, pear-shaped basal outline; the basal cavity is very shallow.

Description: Cusp proclined to erect, upper edge of base very short, flat to broadly convex, curving round evenly into cusp. Posterior margin sharp, straight or very slightly curved, may continue across base as a costa. Anterior margin sharp, straight in lower half, gently curved at mid-height, straight distally. Cusp symmetrically biconvex, strongly deflected inwards.

Basal margin straight anteriorly, curving up posteriorly so that cavity opens to posterior. Basal outline pear-shaped, narrow anteriorly, broadening rapidly at one third of the distance to the posterior. Base gently expanded laterally, anterior margin sharply rounded and a continuation of anterior keel. Cavity very shallow, apex posterior.

Hyaline, thin growth axis runs from basal cavity apex to cusp tip, parallel to posterior margin.

Remarks: Kennedy (1983) included only two species in Eucharodus, E. parallelus and E. toomeyi, although he did note that new, undescribed species were present in Ibexian and early Whiterockian faunas. These are distinguished by elongation of the base, shape of the basal cavity, curvature, flattening and tapering of the cusp and white matter distribution. E. apion is a characteristic, mono-elemental species distinguished from E. parallelus and E. toomeyi, by the symmetrical, pear-shaped basal outline, the very shallow basal cavity and the strong, inward declination of the cusp.

Range: From 195 m to 200 m in the Wandel Valley Formation in Kronprins Christian Land and at 868 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 13

Eucharodus parallelus (Branson and Mehl, 1933)

Pl.7, Figs 4 - 6

* 1933 Drepanodus parallelus, Branson and Mehl, p. 59, pl. 4, Fig. 17

1933 Drepanodus simplex, Branson and Mehl, p. 53, pl. 4, Fig. 2

1933 Drepanodus arcuatus, Branson and Mehl, p. 58, pl. 4, Figs 7, 8, 13

p 1938 Drepanodus subarcuatus, Furnish, p. 320, 328, pl. 41, Figs 25-30, pl. 42, Figs 2, 3 only (non pl. 41, Figs 31, 321

non 1968 Drepanodus parallelus Branson and Mehl; Mound, p. 412, pl. 2, Figs 44-49, pl. 3, Figs 1-11, 58, 60

1970 Drepanodus simplex Branson and Mehl; Barnes and Tuke, p. 86, pl. 19, Figs 8, 12, 13

non 1971 Drepanodus simplex Branson and Mehl; Druce and Jones, p. 74, pl. 13, Figs 1a-4c, text-Fig. 246

non 1971 Drepanodus subarcuatus Furnish; Druce and Jones, p. 74-75, pl. 20, Figs 1a-4c, text-Fig. 24c

1976 "Drepanodus" subarcuatus Furnish; Lindström, text-Fig. 4.1

1978 "Drepanodus" acutus Pander; Fahraeus and Nowlan, p. 457, pl. 2, Fig. 11

1978 "Drepanodus" simplex Branson and Mehl; Fahraeus and Nowlan, p. 457, pl. 2, Fig. 14

? 1979 Drepanodus simplex Branson and Mehl, An, pl. 1, Fig. 6

1980 Drepanodus parallelus Branson and Mehl; Grether and Clark, pl. 1, Fig. 29

1980 Eucharodus parallelus (Branson and Mehl); Kennedy, p. 58-60, pl. 1, Figs 35-38, (synonomy to 1978)

1980 "Drepanodus" parallelus Branson and Mehl; Mayr et al., pl. 32.1, Fig. 1

1982 "Drepanodus" parallelus Branson and Mehl; Ethington and Clark, p. 38-39, pl. 3, Fig. 8

1982 Drepanodus parallelus Branson and Mehl; Repetski, p. 21, pl. 6, Figs 9, 10

1982 Drepanodus parallelus Branson and Mehl; Stouge, p. 35, pl. 3, Figs 19-21

1982 Drepanodus simplex Branson and Mehl; Stouge, p. 36, pl. 3, Fig. 15

1982 Drepanodus simplex Branson and Mehl; Moskalenko, p. 110, pl. 25, Fig. 11

1982 Drepanodus subarcuatus Furnish; Moskalenko, p. 110-11, pl. 26, Figs 15, 16

non 1982 Drepanodus cf. subarcuatus Furnish; Moskalenko, p. 111, pl. 28, Fig. 1

1983 Drepanodus simplex Branson and Mehl; Stouge, pl. 2, Fig. 1

1983 Drepanodus parallelus Branson and Mehl; Stouge, pl. 2, Figs 8, 9

Remarks: The type specimens of Eucharodus parallelus (Branson and Mehl) are hyaline elements from the Jefferson City Formation of Missouri (Kennedy, 1980). Subsequent to Branson and Mehl's (1933) description, Furnish (1938) described similar specimens from the Prairie du Chien Beds of the Upper Mississippi Valley, and named them Drepanodus subarcuatus. Kennedy (1980) noted that Furnish's specimens from the older Oneota dolomite are albid whereas those from the Shakopee Dolomite are hyaline and differ in subtle morphological details; unfortunately no holotype was selected by Furnish (1938) but Kennedy (1980) chose to nominate one of the hyaline Shakopee specimens as lectotype, thus rendering D. subarcuatus a junior subjective synonym of D. parallelus.

Mound (1968) was the first to suggest that D. parallelus, D. arcuatus D. simplex and D.subarcuatus are conspecific and, as first revisor, chose D. parallelus as the name for the species; D. arcuatus being a primary homonym of D. arcuatus Pander, 1856. Mound's specimens do not, however, belong to the same species as those described by Branson and Mehl (1933). Independent studies by Barnes and Tuke (1970) led them to the same conclusion but they chose the name D. simplex. Druce and Jones (1971) considered D. simplex distinct from D. subarcuatus, but Kennedy (1980) noted that their specimens are albid and not related to the species under discussion.

Kennedy (1980) recognised that an apparatus containing D. parallelus, D. simplex and D. arcuatus was essentially monoelemental and did not correspond to the apparatus plan of Drepanodus as established by Lindström (1971), van Wamel (1974) and Löfgren (1978). He therefore erected a new genus, Eucharodus, of which E. parallelus is the type species.

The specimens from Greenland comply well with Kennedy's (1980) redescription of Branson and Mehl's types. The basal cavity outline varies from ovate to sub-circular and may be mildly asymmetrical. The antero-basal angle varies from 70° upwards, although a few specimens have angles as low as 60° (rather lower than in Kennedy's redescription). The postero-basal angle is 50 - 60°. The cusp varies from sub-erect to reclined and is of biconvex cross-section with sub-rounded to keeled margins. Most specimens have sharply rounded to sharp margins. The apparatus is unimembrate, the variations in morphology being continuous with only end members discernable.

Range: E. parallelus occurs between 4 m and 140 m in the Wandel Valley Formation in Peary Land. In Mylius Ericksen Land it was found in the Danmarks Fjord Member and ranged from 1 - 260 m in the Wandel Valley Formation in Kronprins Christian Land. The species has a range of 64 - 1010 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 695

Eucharodus toomeyi(Ethington and Clark, 1964)

Pl. 7, Fig. 7

* 1964 Drepanodus toomeyi, Ethington and Clark, p. 690, pl. 113, Fig. 17, pl. 114, Fig. 22

? 1969 Drepanodus toomeyi, Ethington and Clark; Nieper, pl. 08, Fig. 3

1970 Drepanodus toomeyi, Ethington and Clark; Barnes and Tuke, p. 86, pl. 19, Figs 9-11, text-Fig. 6I

? 1973 Drepanodus toomeyi, Ethington and Clark; Barnes and Poplawski, p. 773, pl. 2, Fig. 10

non 1975 Drepanodus cf. D. toomeyi, Ethington and Clark; Cooper and Druce, p. 573, pl. 1, Figs 15, 17, 18

1982 Drepanodus toomeyi, Ethington and Clark; Ethington and Clark, p. 39-40, pl. 3, Fig. 11

1982 Drepanodus toomeyi, Ethington and Clark; Repetski, p. 22, pl. 7, Fig. 4

1982 Drepanodus toomeyi, Ethington and Clark; Moskalenko, p. 111, pl. 26, Figs 20, 21

Remarks: The specimens at hand conform well with the description given by Ethington and Clark (1964). The species was placed within Eucharodus by Kennedy (1980) since no associated elements of a Drepanodus apparatus had been reported; the hyaline elements were thought by Kennedy to be the components of a unimembrate apparatus. The Greenland material supports this interpretation.

Range: From 10 m to 200 m in the Wandel Valley Formation in Kronprins Christian Land and in a single sample at 4 m in Børglum Elv; 342 - 1390 m section PF 770824-1 on Ella Ø.

Number of Specimens: 21

Eucharodus xyron (Repetski) ?

Pl. 7, Figs 8, 9

p?* 1982 Scolopodus filosus xyron, Repetski, p. 47, pl. 22, Figs 6a-c only (? Figs 1a-e), text-Fig. 7 M

Description: Cusp commonly erect but may be deflected inwards. Upper edge of base very short, rounded, curving evenly into posterior margin. Posterior margin sharp, evenly curved proximally, straight distally. Anterior margin rounded, evenly curved for proximal two-thirds, straight distally. Lateral faces flat or with faint, antero-lateral depressions parallel to anterior margin.

Basal margin straight. Basal outline ovate, narrowing slightly posteriorly. Base unexpanded. Basal cavity relatively deep, posterior parallel to upper edge of base, anterior parallel to anterior margin, apex close to anterior margin.

Hyaline. Conspicuous striae, coarser on posterior of lateral faces.

Remarks: The specimens from Peary Land, Kronprins Christian Land and Ella Ø are closely similar to the holotype of Scolopodus filosus xyron (Repetski, 1982, pl. 22, Figs 6a-c). The holotype has a rounded anterior margin, sharp posterior edge, a weakly expanded base and is finely striate. The Greenland specimens differ only in having a more ovate basal outline and less inflated lateral faces on the base. The second specimen illustrated by Repetski (1982, pl. 22, Figs 1a-c) is more coarsely striate, to the point of being finely costate, and is markedly asymmetrical. Elements of this morphology have not been recovered from Greenland and their assignment to the same species is queried.

S. filosus xyron of Repetski (1982) differs from "Scolopodus" filosus Ethington and Clark in having a cusp that is laterally compressed at the posterior margin, producing a sharp edge. This difference is considered sufficient to warrant a distinction at specific level. A second possibility, that the elements are members of the same apparatus, is ruled out by the lack of co-occurrence in Greenland and the very limited stratigraphic range of this taxon in relation to that of "S." filosus in the El Paso Group (Repetski, 1982).

The apparatus appears to be unimembrate and does not correspond to the apparatus structure of S. sublaevis Pander, the type species of Scolopodus as reconstructed by Fahraeus (1982). It does, however, fit the diagnosis of Eucharodus (Kennedy, 1980) and the species is reassigned to that genus.

Range: E. xyron? occurs from the base to 140 m in the Wandel Valley Formation in Børglum Elv and up to 225 m in Kronprins Christian Land.

Number of Specimens: 30

Genus *FRYXELLODONTUS* Miller, 1969

1969 *Fryxellodontus* Miller, p. 426

Type Species: *Fryxellodontus inornatus* Miller, 1969

"*Fryxellodontus*" sp. A.

Pl. 7, Figs 10 - 12

Remarks: A single specimen of each of three element types was recovered from the Cape Weber Formation. All elements have nodose denticulation on at least one process and are thin walled. The number of processes varies from one to three. The single-processed form has a larger, proclined node ("cusp") at the anterior. The basal cavity extends the full length of the element but is deepest below the anterior node. The element with two processes has them opposed at 90^{o} and the basal cavity occupies the entire lower surface. The element with three processes has them in anterior, lateral and posterior positions, the anterior and posterior ones being sinuous; a larger node is situated centrally and the nodes on the processes are less well-developed than on the other two elements.

The only comparable elements in the Lower Ordovician are *Fryxellodontus? corbotoi* Serpagli and *F? ruedemanni* Landing. These two species are similar in their apparatus plan but elements of *F? ruedemanni* have only one nodose process, the others being smooth (Landing, 1976). These two species were not included in *Fryxellodontus* by Miller (1980), who considered them to be members of a new genus. _"F"._ sp.A. would also be referred to that genus although it possesses an extra nodose "pastinate" element.

Range: At 976 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 3

Genus GLYPTOCONUS Kennedy, 1983

1980 Glyptoconus Kennedy, p. 61

Type Species: Scolopodus quadraplicatus, Branson and Mehl, 1933.

Glyptoconus quadraplicatus Branson and Mehl

Pl. 7, Figs 13 - 16

* 1933 Scolopodus quadraplicatus, Branson and Mehl, p. 63, pl. 4, Figs 14, 15

1964 Scolopodus quadraplicatus Branson and Mehl; Ethington and Clark, p. 699-700, pl. 115, Figs 12, 25

1964 Scolopodus robustus, Ethington and Clark, p. 700, pl. 113, Fig. 7, pl. 115, Figs 18, 21, text-Fig. 2A

1964 Scolopodus triplicatus, Ethington and Clark, p. 700-701, pl. 115, Figs 20, 22, 23, 25, text-Fig. 2C

1964 Scolopodus variabilis, Ethington and Clark, p. 701, pl. 115, Figs 14-16, 19

1979 Scolopodus quadraplicatus Branson and Mehl; An, p. 106-107, pl. 1, Fig. 5

1980 Scolopodus quadraplicatus Branson and Mehl; Grether and Clark, pl. 1, Figs 16, 19

1980 Scolopodus triplicatus Ethington and Clark; Grether and Clark, pl. 1, Figs 34, 35

1980 *Glyptoconus quadraplicatus* (Branson and Mehl); Kennedy, p. 61-63, pl. 1, Figs 39-45, (synonomy to 1978)

1980 cf. *"Scolopodus" quadraplicatus* Branson and Mehl; Mayr *et al.*, pl. 32.1, Fig. 7

1981 *Scolopodus quadraplicatus* Branson and Mehl; An, pl. 2, Figs 1, 8

1981 *Scolopodus quadraplicatus* Branson and Mehl; Repetski and Perry, pl. 2, Fig. 8

1982 *"Scolopodus" quadraplicatus* Branson and Mehl; Ethington and Clark, p. 103-104, pl. 11, Figs 24, 30

1982 *Scolopodus quadraplicatus* Branson and Mehl; Repetski, p. 50, pl. 23, Figs 4, 5

1982 *Scolopodus triplicatus* Ethington and Clark; Repetski, p. 52, pl. 24, Figs 1, 4

1982 *Scolopodus variabilis* Ethington and Clark; Repetski, p. 52, pl. 24, Fig. 5, text-Fig. 84

1982 *"Scolopodus" quadraplicatus* Branson and Mehl; Stouge, p. 43, pl. 3, Figs 5-7

1982 *Scolopodus quadraplicatus* Branson and Mehl; Moskalenko, p. 138-39, pl. 27, Figs 12, 16, 17

1983 *"Scolopodus" quadraplicatus* Branson and Mehl; Stouge, pl. 2, Figs 3-5

1983 *Glyptoconus quadraplicatus* Ni *in* Zeng *et al.*, pl. 10, Figs 21,

1983 *Glyptoconus quadraplicatus* Ni *et al.*, pl. 1, Fig. 28

Remarks: Elements with similar morphologies to Scolopodus quadraplicatus Branson and Mehl were described by Ethington and Clark (1964) and given the names S. robustus, S. triplicatus and S. variabilis. Specimens with the morphologies of S. quadraplicatus and S. triplicatus from Greenland, like those from Missouri (Kennedy, 1980) and Utah (Ethington and Clark, 1982), show a complete intergradation between forms with two lateral grooves ("S. quadraplicatus") and those with only one lateral groove ("S. triplicatus"). It is clear that they belong in the same apparatus, as concluded by Kennedy (1980) and Ethington and Clark (1982). An additional type of element is present in the Greenland faunas with no groove on one lateral face and only an extremely faint lateral groove on the opposite face. This is effectively a continuation of the transition from S. quadraplicatus to S. triplicatus to a form which has only the posterior groove well-developed.

The relationship of S. robustus and S. variabilis to this apparatus has been a matter of debate. Repetski (1975) included them in the apparatus of S. quadraplicatus, considering S. robustus to be an extreme variant of S. variabilis. Although reverting essentially to form taxonomy, Repetski (1982) still treated S. robustus as a junior synonym of S. variabilis. In his thorough review of G. quadraplicatus, Kennedy (1980) included S. variabilis as a possible morphological variant of the apparatus in which the two postero-lateral costae are more developed than the antero-lateral ones. Kennedy (1980), however, omitted S. robustus from synonomy with G. quadraplicatus on the grounds that it had not been found in the Jefferson City Formation. S. variabilis is a common component of faunas containing G. quadraplicatus in Greenland although S. robustus is much rarer. I include both S. variabilis and S. robustus as junior subjective synonyms of G. quadraplicatus.

The gargantuan element of Kennedy (1980) is also present in my collections. This is a large, robust element which has deep grooves and, frequently, secondary costa. Kennedy suggested that these elements are not simply oversized versions of normal elements but reflect reponses to environmental stress.

The apparatus of G. quadraplicatus thus contains a wide range of forms, particularly with respect to the distribution of costae and grooves. The most common elements have two lateral grooves and a posterior groove bounded by antero-lateral and postero-lateral costae. In some specimens one lateral groove may be very faint or absent and in a few specimens the opposite lateral groove is correspondingly reduced. The postero-lateral costae may be closely spaced and in a few extreme specimens they are very close, with a much reduced posterior groove. The elements may show the development of bifid postero-lateral costae and some specimens have secondary costae running along the lateral grooves. Elements may be striate, the striae not showing preferential development on any one particular type of element.

This apparatus style does not correspond to that of Scolopodus sublaevis, the type species of Scolopodus, as determined by Fahraeus (1982) lacking, in particular, a "scandodontiform" element. Additionally, the elements are not multicostate. To accommodate these differences, Kennedy (1980) erected the genus Glyptoconus. The smooth transitions between elements makes it very difficult to subdivide them into different element types. The apparatus was considered by Kennedy (1980) to consist of symmetrical and asymmetrical types and Barnes et al. (1979) classified it as a Type IB apparatus. If elements of the types referred to S. variabilis and *S. robustus* are included, this may warrant transfer to a Type IA category. In such an apparatus, "*Scolopodus quadraplicatus*" would be the s element, "*Scolopodus triplicatus*" the t and "*S. variabilis*" and "*S. robustus*" the u element. Smooth transition does not take place from s through to u but from s to t and s to u.

Eucharodus parallelus very commonly occurs in association with *G. quadraplicatus* and it has been mentioned by Kennedy (1980) and Ethington and Clark (1982) that perhaps they belonged within the same apparatus. Kennedy (1980) dismissed this on the basis of differing ranges, the lack of transitional forms and the absence of any similar Ibexian apparatuses. I concur with this view and would add that the abundance peaks of the two species in Greenland are often substantially different.

Acontiodus staufferi Furnish and *Ulrichodina deflexa* Furnish were included as part of the apparatus of *G. quadraplicatus* by Landing and Barnes (1981) but this is not supported by the collection from Greenland. *U. deflexa* does have a similar cross-section to quadricostate elements of *G. quadraplicatus* but it has not been recovered from Greenland, and *A. staufferi* is a very rare component of Greenland faunas.

Range: *G. quadraplicatus* ranges from 4 m to 177 m in the Wandel Valley Formation in Peary Land. It has been recovered from the Danmarks Fjord Member in Mylius-Erichsen Land and occurs between 0 and 140 m in the Wandel Valley Formation in Kronprins Christian

Land. On Ella Ø, the species ranges from 64 m to 1345 m in section PF 770824-1.

Number of Specimens: 739

Glyptoconus aff. G. quadraplicatus (Branson and Mehl)

Pl. 7, Figs 17, 18

? 1973 Scolopodus aff. S. quadraplicatus Branson and Mehl; Barnes and Poplawski, p. 787, pl. 1, Fig. 11

? 1982 "Scolopodus" sp. cf. "S." quadraplicatus Branson and Mehl; Stouge, pl. 7, Figs 9, 14

Remarks: Specimens of G aff. G. quadraplicatus differ from G. quadraplicatus in having a more widely expanded basal cavity and subdued, but narrow, lateral and posterior grooves. All specimens recovered were of the asymmetrical morphotype with only one grooved lateral face. The first occurrence of G. aff. G. quadraplicatus directly succeeds the last of G. quadraplicatus. If this change of morphology proves to be the norm it may be of biostratigraphic value.

The specimens identified as Scolopodus aff. S. quadraplicatus by Barnes and Poplawski (1973) and as "Scolopodus" sp. cf. "S." quadraplicatus by Stouge (1982) show the flared basal cavity and narrow grooves seen in the Greenland specimens but have much more deeply incised lateral and posterior grooves.

Range: From 195 to 221 m above the base of the Wandel Valley Formation in central Peary Land and from 168 to 238 m above the base of PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 8

Genus *HISTIODELLA*, Harris 1962

1962 *Histiodella* Harris, p. 207

Type Species: *Histiodella altifrons* Harris, 1962

Histiodella holodentata Ethington and Clark, 1982

Pl. 8, Figs 1 - 5

* 1982 *Histiodella holodentata*, Ethington and Clark, p. 47-8, pl. 4, Figs 1, 3, 4, 16, (synonomy to 1979)

1982 ? aff. *Loxodus* sp.; Ethington and Clark, p. 53, pl. 5, Fig. 4.

p 1982 *Histiodella* sp.; McHargue, pl. 1, Fig. 21 only.

p 1983 *Histiodella* sp.; Stouge, pl. 7, Figs 1, 2 only (*non* Fig. 3)

Remarks: Ethington and Clark (1982) did not come to a conclusion as to the relationship of specimens they described as ?aff. *Loxodus* sp. although they did note that they occurred with *H. holodentata* in both the Antelope Valley Formation and the Pogonip Group. These elements again occur with *H. holodentata* in the Wandel Valley Formation of central Peary Land where, in addition, intermediates are found, in which the largest denticle is more centrally located with a consequent reduction in the number of anterior denticles.

McHargue (1982) concluded that the apparatus of *Histiodella* was seximembrate and composed of bryantodiform, short bryantodiform, twisted bryantodiform, zygognathiform, trichonodelliform and oistodiform elements. The most abundant element of H. holodentata corresponds to the bryantodiform element of McHargue (1982) and a possible trichonodelliform element was reported by Ethington and Clark (1982, pl. 4, Fig. 16). The bryantodiform elements from Greenland differ in slight details from the description given by Ethington and Clark (1982). There may be as few as four denticles posterior to the main denticle and this may be rather more or less than the quarter blade length they cited. The element described as ?aff. Loxodus sp. Ethington and Clark (1982) is probably the short bryantodiform element of H. holodentata although it is very different from the denticulate morphotypes figured by McHargue (1982) which have three denticles anteriorly and are serrate posteriorly. The short bryantodiform element of H. holodentata may have been derived from precursors of this morphology.

Range: From 214 to 221 m above the base of the Wandel Valley Formation and at 118 m below the top of the formation in central Peary Land.

Number of Specimens: 19 bryantodiform, 4 intermediate, 4 short bryantodiform.

Histiodella sp. A.

Pl. 8, Fig. 6

?* 1982 Histiodella donnae, Repetski, p. 25-6, pl. 8, Figs 6-7, text-Fig. 5I

Remarks: The element is palmate with a convex anterior face and a concave posterior face with median costa. Incipient denticles are visible along the edges, which are convex in outline. The basal cavity is shallow and limited to the area directly below the posterior costa. The element is albid in all but the basal region.

The element resembles the Sa ("trichonodelliform") elements of Histiodella figured by McHargue (1982, pl. 2, Figs 16-21, 24-26). The only species of Histiodella reported from the Lower Ordovician is H. donnae Repetski. An Sa element of this species was mentioned, but not illustrated, by Repetski (1982) and H. sp. A. may prove to be that element.

Range: H. sp. A. was recovered 880 m up the Cape Weber Formation on Ella Ø.

Number of Specimens: 1

Histiodella? sp. B.

Pl. 8, Fig. 7

Remarks: A single specimens of a bladed element was recovered from the Amdrup Member of the Wandel Valley Formation. The element is triangular in lateral profile with the cusp situated towards the anterior. The anterior margin is adenticulate and the posterior margin bears four denticles. The basal margin is straight and the basal cavity is a flat plate, widest anteriorly. The element is comparable to the bryantodontiform element of Histiodella figured by McHargue (1982, pl. 1, Figs 1 - 21).

Range: Found at 195 m in the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 1

Genus JUANOGNATHUS Serpagli, 1974

1974 Juanognathus Serpagli, p. 49

Type Species: Juanognathus variabilis Serpagli, 1974.

Remarks: The apparatus was classified by Barnes et al. (1974) as a type IA but with a particularly smooth transition between the s, t and u elements.

Juanognathus variabilis Serpagli, 1974

Pl. 8, Figs 8, 9

* 1974 Juanognathus variabilis, Serpagli, p. 49-50, pl. 11, Figs 1a-7c, pl. 22, Figs 6-17, text-Fig. 8.

1982 Juanognathus variabilis Serpagli; Ethington and Clark, p. 50, pl. 5, Figs 8-10, 17, (synonomy to 1974)

1982 Juanognathus variabilis Serpagli, Repetski, p. 27, pl. 8, Figs 9a-c, pl. 9, Figs 1a-2c, text-Fig. 5L.

1982 Juanognathus variabilis Serpagli; Stouge, pl. 7, Figs 8, 12.

Remarks: Only a very small number of elements were recovered. Some of the specimens have sharp posterior carinae.

Range: Found at 185 m in the Wandel Valley Formation in Kronprins Christian Land. From 935 m to 1060 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 4

Juanognathus sp. nov. A.

Pl. 8, Fig. 10

Description: Only u elements have been recovered. Upper edge of base long, curving evenly into proclined cusp. Anterior face broad, evenly rounded, terminated by lateral costae. Costae sharply rounded posterior faces flat, dying out towards basal margin, directed postero-laterally. Posterior face semi-circular in cross-section. Element usually symmetrical but costae may be asymmetrically placed.

Basal margin straight, basal outline circular to sub-triangular with apex posterior. Basal cavity deep, apex anterior. Albid in all except basal area.

Remarks: The elements are generally similar to the u elements of *J. variabilis*, but differ in that none of the specimens have short adenticulate processes, nor is the cusp twisted. Although Serpagli (1974) included specimens in *J. variabilis* whose costae do not reach the basal margin, the absence of any of the characteristic element morphologies or symmetry transitions of *J. variabilis* preclude inclusion of the Greenland specimens. *J*. sp. A. seems to be a closely related but distinct species.

The species also bears some similarity to large specimens of *Protopanderodus leonardii* but differs in being antero-posteriorly, rather than laterally, compressed and in having more promiment costae.

Range: From 848 to 880 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 16

Genus _JUMUDONTUS_ Cooper, 1981

1971 New Genus B Sweet, Ethington and Barnes, pl. 1, Fig. 34

1981 _Jumudontus_ Cooper, p. 169

Type Species: _Jumudontus_ _gananda_ Cooper, 1981

Jumudontus _gananda_ Cooper, 1981

Pl. 8, Fig. 11

1971 New Genus B, Sweet, Ethington and Barnes, pl. 1, Fig. 34

* 1981 _Jumudontus_ _gananda_, Cooper, p. 170-2, pl. 31, Fig. 13

1982 _Jumudontus_ _gananda_ Cooper; Ethington and Clark, p. 51-2, pl. 2, Figs 9, 10 (synonomy to 1981)

1982 "_?Spathognathodus_ sp." Ethington and Clark; Repetski, p. 53, pl. 25, Figs 8a-10c

Remarks: This characteristic species is an important zonal taxon in the Ibexian, being used in the zonal schemes of Ethington and Clark (1982) and Harris and Repetski (pers. comm., 1982). Only a single specimen was recovered but it falls well within the range of morphology of previously figured specimens.

Range: At 848 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 1

Genus LEPTOCHIROGNATHUS Branson and Mehl, 1943

1943 *Leptochirognathus* Branson and Mehl, p. 377

Type Species: *Leptochirognathus quadrata* Branson and Mehl, 1943

Leptochirognathus sp.

Pl. 8, Fig. 12

Remarks: A single, poorly preserved specimen was found 184 m above the base of the Wandel Valley Formation in central Peary Land. The cusp is broken but there appears to have been only a single denticle posterior to the cusp.

Genus MACHETICODUS gen. nov.

Type Species: Scolopodus carlae Repetski, 1982.

Derivation of Name: machetikos (Gr.), warlike, odous (Gr.) tooth; with reference to the spear-shaped outline of the element.

Diagnosis: Apparatus unimembrate. Elements antero-posteriorly compressed, striate, albid. Basal cavity very shallow and symmetrical or asymmetrical with respect to cusp.

Remarks: In addition to the specimens of the type species described by Repetski (1982), specimens figured as Juanognathus? sp. A. by Stouge (1982, 1983) may represent a species of Macheticodus, but they are very poorly preserved. A second, new, species of Macheticodus, M. lekiskus, is described below.

Macheticodus carlae (Repetski, 1982)

Pl. 8, Figs 13, 14

* 1982 Scolopodus carlae, Repetski, p. 49 - 50, pl. 23, Figs. 1-3.

Remarks: Repetski (1982) included this species in Scolopodus Pander. The apparatus type and element morphology do not, however, compare with the type species, as described by Fahraeus (1982), nor do they conform with the diagnoses of any other available genus.

The specimens of S. carlae from Greenland are closely similar to those described by Repetski (1982). The basal cavity is very shallowly conical with a very small apex. The rim surrounding the basal cavity is not always perfectly symmetrical and may be extended unequally to one side. The cavity itself may be offset from the midline. The cusp is antero-posteriorly compressed with evenly curved anterior and posterior faces.

Range: From 868 to 976 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 6

Macheticodus lekiskus sp. nov.

Pl. 8, Figs 15 - 18

Derivation of Name: lekiskos (Gr.), plate; with reference to the morphology of the basal cavity.

Diagnosis: A species of Macheticodus with prominent, narrow costae on the posterior face. Basal cavity reduced to an extremely small pit or subcircular disc with pit.

Description: Cusp antero-posteriorly compressed, biconvex in cross-section; posterior face more rounded, anterior face almost flat, lanceolate in posterior profile, maximum width at ⅓ height, narrows gradually to distal tip, tapers more rapidly proximally to point. Lateral edges strongly convex as far as maximum width then gently convex. Anterior face striate. Posterior face coarsely striate, may bear low, median carina. Basal regions astriate.

Basal cavity reduced to extremely small, shallow pit at proximal tip of cusp; alternatively, cusp may terminate proximally at subcircular basal disc. Disc projects from cusp, has rounded edges, commonly located oblique to main axis; facing latero-basally, basal pit on disc always situated at proximal tip of cusp.

Remarks: *M. lekiskus* is distinguished from *M. carlae* in having a more coarsely striate posterior face, a cusp which tapers proximally to a point and a basal cavity of rather different character. Those elements of *M. lekiskus* with a basal pit are clearly distinct and those with a basal disc differ in that the disc lacks a rim and has rounded edges, whereas *M. carlae* has a definite, though shallow, cavity. The basal pit of *M. lekiskus* may be equivalent to the basal cavity apex of *M. carlae*.

M. lekiskus has been reported from the Canadian Arctic Islands by Nowlan (1976) in an unpublished PhD thesis and from Washington Land (Kurtz and Miller, GGU int. rept.). It occurs in a stratigraphically older sample than those containing *M. carlae* in East Greenland.

Range: From 20 m to 200 m in the Wandel Valley Formation in Kronprins Christian Land and at 848 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 37

Genus MULTIOISTODUS Cullison, 1938

1938 Multioistodus Cullison, p. 226

1964 Multioistodus (Trirhadicodus) Harris, p. 117

1964 Multioistodus (Dirhadicodus) Harris, p. 114

1965 Multioistodus (Neomultioistodus) Harris and Harris, p. 42-43

Type Species: Multioistodus subdentatus Cullison, 1938

Remarks: The apparatus of the type species, M. subdentatus Cullison, is quadrimembrate, consisting of an Sa - Sd transition series (Lindström, 1964; Rexroad, Droste and Ethington, 1982). However, some species with an Sa - Sd transition series of elements very similar to those of M. subdentatus possess a fifth element, here considered to be an M element. This element, termed scandodiform by Ethington and Clark (1982), is similar to the Sc but differs in having a basal cavity which is strongly flared on the inner face and a cusp which has a strongly convex inner face and is deflected inwards. Species with such an apparatus will, in time, need to be removed from Multioistodus. Until the apparatuses of closely related genera, such as Tricladiodus Mound, are reconstructed it would not, however, be wise to assign them to a new genus. For the present, multioistodontan species with a quinquimembrate apparatus are referred to Multioistodus?, the two examples from Greenland being M? celox sp. nov. and M? compressus Harris and Harris.

Multioistodus auritus (Harris and Harris, 1965)

Pl. 8, Fig. 19

* 1965 Acodus auritus, Harris and Harris, p. 34-35, pl. 1, Figs 2a-c

1969 Multioistodus compressus (Harris and Harris); Bradshaw, p. 1153-55, pl. 133, Figs. 1-10, pl. 136, Figs 2-4.

1982 Multioistodus auritus (Harris and Harris); Ethington and Clark, p. 57-8, pl. 6, Figs 1-4, (synonomy to 1978)

Remarks: A single Sa element was recovered from the Narwhale Sound Formation. The apparatus of M. auritus was first reconstructed, but misidentified, by Bradshaw (1969) and was fully described by Ethington and Clark (1982).

Range: 1380 m above the base of section PF 770824-1 on Ella Ø.

Number of Specimens: 1

Multioistodus aff. auritus (Harris and Harris, 1965)

Pl. 8, Fig. 20

?p 1965b Multioistodus subdentatus Cullison; Mound, p. 25, pl. 3, Fig. 17 only (non figs 18, 20, 25)

1982 ?Multioistodus auritus (Harris and Harris); Ethington and Clark, p. 58, pl. 6, Figs 5-7

Remarks: A small number of specimens from the Wandel Valley Formation of central Peary Land are similar to those described as ?Multioistodus auritus by Ethington and Clark (1982). Most are Sc elements but one is a poorly preserved Sa or Sb element. The element should probably be placed in a new species but the small number of specimens and incomplete apparatus preclude this.

The species is found in samples containing Paraprioniodus costatus (Mound) and "Cordylodus" sp.B. The single sample which yielded Ethington and Clark's (1982) specimens also contained P. costatus.

Range: Found 214 - 221 m above the base and 118 m below the top of the Wandel Valley Formation in central Peary Land.

Number of Specimens: 1 Sa/Sb, 14 Sc.

Multioistodus? celox sp. nov.

Pl. 9, Figs 1 - 10

Derivation of Name: celox (L.), yacht, cutter; in reference to the characteristic morphology of the cusp and denticles.

Diagnosis: A hyaline quinquimembrate species of Multioistodus-type comprising an Sa - Sd transition series and an M element with a base strongly expanded inwards. The denticles of all elements are very long, laterally compressed and gently curved.

Description:

Sa element

Cusp reclined to recurved, gently curved; anterior margin rounded, posterior margin keeled; each lateral face bears a hair-line costa situated on midline or just anterior. Denticles of each lateral process joins lateral costae, antero-lateral in position, antero-posteriorly compressed, postero-laterally directed, up to half cusp height, one may be longer than other. Posterior process joins posterior margin keel and bears a single denticle. Denticle laterally compressed, gently curved, directed posteriorly; axis almost horizontal and a continuation of posterior process, sub-equal in length to cusp.

Basal margin straight; basal outline triangular, apex of triangle posterior.

Sb element

Cusp erect to reclined, only slightly curved; anterior and posterior margins keeled; strongly laterally compressed. One lateral face has hair-line median costa. Lateral process joins median costa, single denticle erect, antero-posteriorly compressed, sharp-edged. Posterior margin produced as erect to reclined, laterally compressed denticle deflected to opposite side from antero-lateral denticle.

Basal margin straight; basal outline triangular, apex of triangle posterior; basal cavity shallow, apex anterior.

Sc element

Cusp erect, laterally compressed, may be deflected slightly inwards. Anterior margin keeled, may be deflected inwards. Posterior margin keeled. Inner face flat; outer face gently rounded. Posterior margin produced as denticle. Denticle erect, straight to very gently curved, laterally compressed, up to half height of cusp.

Basal margin straight to convex; basal outline narrow and lenticular; basal cavity shallow, apex anterior.

Sd element

Cusp recurved, gently curved, anterior margin sharp to sharply rounded, posterior margin sharp; hair-line median costae on lateral faces produced as denticles. One denticle recurved, gently curved, laterally compressed, sharp-edged, directed postero-laterally and upwards, up to two-thirds cusp height. Opposite denticle straight to gently curved, laterally compressed, sharp-edged, directed posteriorly and downwards, up to two-thirds cusp height. Posterior margin joins posterior process at an angle. Denticle on posterior process laterally compressed, sharp-edged, sub-equal in length to cusp, directed posteriorly.

Basal margin straight; basal outline diamond-shaped, widest medially; basal cavity shallow, apex central.

M element

Cusp erect, bowed inwards, anterior margin sharp and deflected inwards. posterior margin sharp; outer face broadly rounded, inner face more convex. Posterior margin meets posterior process at acute angle. Posterior denticle erect, straight, laterally compressed, sharp-edged, up to half height of cusp.

Basal margin straight; basal outline lenticular; basal cavity shallow, strongly flared inwards, outer face broadly convex, apex central.

All elements are hyaline.

Remarks: Although found in only a single sample, the distinctive denticle morphology of *M? celox* permits confident assignment to a new species. The Sd element is the most characteristic and the one which differs most greatly from the corresponding element of *M? compressus*. One lateral denticle projects posteriorly and upwards but the second is directed posteriorly and downwards. The Sa and Sd elements have posterior denticles which are sub-equal in length to the cusp and are very strongly recurved, almost being continuations of the posterior process.

M? celox occurs above *M? compressus* in the Wandel Valley Formation.

Range: Found at 214 m above the base of the Wandel Valley Formation in central Peary Land.

Number of Specimens: 27 Sa, 64 Sb, 73 Sc, 24 Sd, 40 M.

Multioistodus? compressus Harris and Harris, 1965

Pl. 9, Figs 11 - 20

* 1965 *Multioistodus (Neomultioistodus) compressus*, Harris and Harris, p. 43-4, pl. 1, Figs 7a-c.

1982 *Multioistodus compressus?* Harris and Harris; Ethington and Clark, p. 58-9, pl. 6, Figs 8-11, 16 (synonomy to 1978)

Remarks: All of the five elements described by Ethington and Clark (1982) were recovered from the Wandel Valley Formation and comply well with the description of specimens from the Ibex area. Ethington and Clark (1982) considered the diagnostic features to be the presence of an M element (scandodiform of Ethington and Clark, 1982) and the morphology of the Sc element with its antero-basal extension and reclined, laterally compressed posterior denticle. The Sa, Sb and Sd elements were not thought to be distinguishable from those of *M. subdentatus*.

Range: From 168 to 195 m above the base of the Wandel Valley Formation in central Peary Land and at 136 m above the base of section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 4 Sa, 7 Sb, 12 Sc, 6 Sd, 6 M.

"Multioistodus" sp.A.

Pl. 9, Figs 21, 22

Description: Only one element of the apparatus has so far been recovered. Cusp erect, straight, laterally compressed; anterior margin keeled, one lateral face flat, opposite face carinate; posterior margin sharp. Posterior denticle meets posterior margin at very acute angle, erect, laterally compressed, sharp-edged, axis parallel to cusp; two-thirds height of cusp.

Basal margin concave; basal outline greatest in width beneath cusp, one face flat, opposite expanded as continuation of carina, tapers posteriorly; basal cavity shallow, apex at point of greatest width. Element albid in all but base.

Remarks: The few specimens recovered are of a single element type which is broadly similar to the Sc element of Multioistodus and Wandelia. No elements corresponding to the remainder of such an apparatus were present in the three samples which yielded "M". sp. A. and the apparatus of this species may be unimembrate and hence not assignable to Multioistodus.

Range: From 214 to 221 m above the base of the Wandel Valley Formation in Børglum Elv and at 110 m above the base of section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 6

Genus OEPIKODUS Lindström, 1955

1955 *Oepikodus* Lindström, p. 570

Type Species: *Oepikodus smithensis* Lindström, 1955

Remarks: The taxonomic status and apparatus structure of *Oepikodus* have been the subject of much discussion in the literature. The genus was erected by Lindström (1955) for elements with a denticulate posterior process, antero-lateral costae which may be developed as short adenticulate processes, and a suberect cusp. The multi-element apparatus of *Oepikodus* was later established by Lindström (1971) who included pastinate, quadriramate and geniculate coniform elements and assigned it to *Prioniodus* Pander. The trimembrate concept has continued to be used by numerous authors (e.g. Serpagli, 1974; van Wamel, 1974; Löfgren, 1978 and Bergström, 1981).

Differences in the apparatus structures of *Prioniodus elegans* Pander and *P. evae* of Lindström (1971), principally the presence of adenticulate lateral processes and the apparent lack of an Sb element in *P. evae* led Bergstrom and Cooper (1973) to suggest that apparatuses of this type should be placed within the subgenus *Oepikodus*. This recommendation was followed by Serpagli (1974) and Löfgren (1978)

Oepikodus was given full generic status by van Wamel (1974) on the basis of its supposed trimembrate apparatus and by Fahraeus and Nowlan (1978) on the basis of a reduced transition series and possession of an adenticulate geniculate coniform; the latter concept is used here.

The symmetry transition series of Oepikodus was first recognised by Ethington and Clark (1971) who included three, possibly four, elements. Fahraeus and Nowlan (1978) noted that the symmetry transition takes place within the generalised "oepikodiform" of other authors. In his description of El Paso conodonts, Repetski (1982) included an Sa - Sd transition series in Oepikodus.

The apparatus hence includes a pastinate P element and dolabrate Sa - Sc elements with the symmetry transition marked by costae. The Sa is bicostate, the Sb unicostate and the Sc acostate. Repetski (1982) included this Sa as an "Sd" and recognised an "Sa" with no anticusp. A geniculate coniform M element completes the apparatus.

The apparatus was classified as Type IV D by Barnes et al. (1979), although a fourth S element would transfer it to Type IV A. Bergström (1981) placed the genus in the monotypic Oepikodontidae.

Oepikodus communis (Ethington and Clark, 1964)

Pl. 10, Figs 1 - 8

? 1941 Cordylodus quadratus, Graves and Ellison, p. 10-11, pl. 1, Figs 22-25.

? 1941 Cordylodus multidentatus, Graves and Ellison, p. 10, pl. 1, Fig. 21.

1964 Gothodus communis, Ethington and Clark, p. 690, 692, pl. 114, Figs 6, 14.

1964 Oepikodus equidentatus (Graves and Ellison), Ethington and Clark, p. 692 - 693, pl. 113, Figs 6, 8, 10, 11, 14.

1964 ?*Oistodus longiramis* Lindström, Ethington and Clark, p. 693, pl. 114, Figs 2, 7.

1964 *Subcordylodus* sp. aff. *S. delicatus* (Branson and Mehl); Ethington and Clark, p. 701-702, pl. 115, Figs 1, 5, 7, 10.

1965 *Gothodus communis* Ethington and Clark; Ethington and Clark, p. 193, pl. 1, Fig. 21.

1965 *Oepikodus quadratus* (Graves and Ellison); Ethington and Clark, p. 193-194, pl. 2, Fig. 9.

1965 *Oistodus longiramis* Lindström; Ethington and Clark, p. 195-196, pl. 1, Fig. 5.

1965 *Subcordylodus* sp.; Ethington and Clark, p. 201-202, pl. 2, Fig. 6.

1972 *Gothodus communis* Ethington and Clark; Ethington, p. 24, pl. 1, Fig. 20.

(?p) 1972 *Oepikodus quadratus* (Graves and Ellison); Ethington, p. 24, pl. 1, Figs 24-26, ?27.

1972 *Oistodus longiramis* Lindström; Ethington, p. 23, pl. 1, Fig. 3.

1973 *Prioniodus evae communis* (Ethington and Clark); McTavish, p. 45-46, pl. 3, Figs 27, 29-32, 37, text-Figs 6a-e.

? 1974 *"Plectodina"* sp.; Serpagli, p. 49-50, pl. 16, Figs 5a, b, pl. 27, Fig. 9.

1974 *Prioniodus (Oepikodus) intermedius*, Serpagli, p. 53-57, pl. 15, Figs 1a-4b, pl. 27, Figs 1-7, pl. 31, Figs 2a-b, text-Figs 15d-f.

1980 Oepikodus communis (Ethington and Clark); Kennedy, p. 49, pl. 2, Figs 33, 34.

? 1981 Baltoniodus communis (Ethington and Clark); An, pl. 4, Figs 20-23, 25-29.

1982 Oepikodus communis (Ethington and Clark); Ethington and Clark, p. 61-62, pl. 6, Figs 18, 22, 25, (synonomy to 1981).

1982 Prioniodus evae Lindström, Teraoka et al., pl. 2, Figs 3-6, 8.

1982 Prioniodus n. sp. C McTavash (sic); Teraoka et al., pl. 2, Figs 7, 10.

? 1982 Prioniodus navis Lindström; Teraoka et al., pl. 2, Fig. 11.

1982 Oepikodus communis (Ethington and Clark); Repetski, p. 30-31, pl. 11, Figs 5-8, 10, 12.

1982 Oepikodus communis (Ethington and Clark); Stouge, p. 38-39, pl. 4, Figs 9-12.

1982 Oepikodus sp. cf. O. communis (Ethington and Clark); Stouge, p. 40, pl. 6, Figs 17-20.

1983 Oepikodus communis (Ethington and Clark); Stouge, pl. 3, Figs 4-6.

1983 Oepikodus sp. cf. O. communis (Ethington and Clark); Stouge, pl. 4, Fig. 10.

Remarks: Graves and Ellison (1941) described ?Cordylodus quadratus from the Marathon Limestone of Texas. This was considered to be a senior synonym of _Oepikodus_ _equidentatus_ Ethington and Clark, 1964 by Ethington and Clark (1971) and Ethington (1972) and hence of _Oepikodus_ _communis_ (Ethington and Clark). In their description of the Ibex fauna, Ethington and Clark (1982) preferred, however, not to formalise a revision until a restudy of the Marathon Limestone conodonts had confirmed synonomy. Should such a study show that the two taxa are conspecific, _O. quadratus_ will have priority.

O. communis was considered to be a subspecies of _Prioniodus_ _evae_ by McTavish (1973) because of the similarity of the pastinate elements. Subsequent workers have considered the absence of denticles on the anterior and lateral processes of _O. communis_ sufficient to warrant a distinction at specific level.

Serpagli (1974) erected a species, _Prioniodus_ _(O.) intermedius_ for specimens he considered to be intermediate between _O. smithensis_ and _O. communis_. This was distinguished from _P. (O.) communis_ mainly on details of the processes, with the pastinate element having a more posteriorly deflected anterior process and a less arched posterior process that curved up distally. The ramiform elements differed in possessing hindeodellid denticles and the coniform had a longer anterior process. All of these characters are seen as variations of _O. communis_ in the Greenland faunas and _O. intermedius_ is here treated as a junior subjective synonym of _O. communis_, following Ethington and Clark (1982) and Repetski (1982). _O. communis_ was recovered from the St. George Group of Newfoundland by Stouge (1982) together with specimens he described as _O._ sp. cf. _O. communis_, which he considered to be allied to

O. intermedius. All of his figured specimens are within the range of variation of O. communis.

Repetski (1982) included a sixth member in the apparatus of O. communis but did not figure it. The extra element would be the Sa of the transition series with the present Sa reassigned to an Sd position. This Sa is distinguished by the lack of anticusp. Such an element was figured and questionably included in O. quadratus by Ethington (1972) but is not present in the Greenland collections nor in the large collection described by Ethington and Clark (1982). Both of these collections are, however, smaller than that described by Repetski.

Clusters of Oepikodus communis recovered from the Cape Weber Formation give an insight to the relative positions of the elements within the apparatus and are described in Chapter 7.

Range: O. communis occurs from 55 m to 200 m in the Wandel Valley Formation in Kronprins Christian Land. The species has a range of 514 - 1161 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 186 P elements, 94 Sa elements, 92 Sb elements, 220 Sc elements, 131 M elements.

Oepikodus? marathonensis (Bradshaw, 1969)

Pl. 10, Figs 9 - 15

1965b Cordylodus flexuosus (Branson and Mehl); Mound, p. 14, pl. 1, Fig. 25.

1965b Gothodus communis Ethington and Clark; Mound, p. 20, pl. 2, Figs 24, 25.

? 1965b Oistodus longiramis Lindström; Mound, p. 28, pl. 3, Fig. 32.

? 1967 Cordylodus? sp.; Higgins, Fig. 2.6.

1969 Gothodus marathonensis, Bradshaw, p. 1151, pl. 137, Figs 13-15, text-Figs 3 S, T, U.

1969 Paracordylodus sp.; Bradshaw, p. 1160-61, pl. 137, Figs 12, 13.

1969 Roundya sp.; Bradshaw, p. 1160-61, pl. 137, Fig. 17, text-Fig. 3A.

1978 Prioniodus cf. P. sp. C McTavish; Tipnis et al., pl. 3, Fig. 6.

1978 Cordylodiform? element A; Tipnis et al., pl. 3, Fig. 8.

p 1982 "Microzarkodina" marathonensis (Bradshaw); Ethington and Clark, p. 55-56, pl. 5, Figs 14, 20, 23, 24, 27, (non Fig. 19)

? 1982 Cordylodus oklahomensis Müller; Teraoka et al., pl. 2, Fig. 11.

1982 Microzarkodina? cf. M. marathonensis (Bradshaw); Repetski, p. 28-29, pl. 10, Figs 1-7, 9.

1982 ?Microzarkodina marathonensis (Bradshaw); Stouge, p. 38, pl. 7, Figs 1-5.

Description:

P element

Cusp and denticles reclined, sharp-edged. Anterior margin keeled, may be deflected inwards. Antero-basal angle 70° and sharply curved. Posterior process may be slightly twisted. Ridge may run parallel to basal margin a short distance above it.

Basal margin below cusp slightly convex but more or less a straight line from antero-basal corner to posterior end of process. Basal cavity shallow, anterior margin short, posterior margin extended under process; apex below posterior margin of cusp.

Ramiform elements

Sc element generally similar to P but has long anticusp, may be longer than cusp. Denticles more reclined distally. Posterior process curves around evenly through approximately 90° into posterior margin of anticusp. Anterior margin keeled, may be deflected inwards.

Sb element has costa along one lateral face of cusp crossing basal cavity apex, curving posteriorly to meet basal margin at point of maximum basal cavity width. Anterior keel may be deflected to opposite lateral face.

There is a very smooth transition from Sb to Sa, with a flat or broadly rounded anterior face developing. One antero-lateral costa is then directed slightly anteriorly, the opposite antero-lateral costa slightly posteriorly. In Sa end-members the costae are normal to the plane of the posterior process. Subdivision of intermediate elements between Sb and Sa is necessarily subjective. Sc elements may show development of an incipient lateral costa and there is more of a morphological jump from Sb to Sc than from Sa to Sb.

White matter occupies all of the denticles and all but the basal part of the cusp.

M element

Coniform, geniculate. Anterior margin curves evenly into antero-basal corner; anticusp relatively short. Posterior process relatively short, may bear keel on upper edge. Basal cavity weakly expanded, does not affect straight line of basal margin from anticusp to posterior process.

Remarks: The species was first illustrated by Mound (1965b) who referred it to Gothodus communis Ethington and Clark. Higgins (1967) illustrated a fragment which may belong here, but well-preserved material was described by Bradshaw (1969) as Gothodus marathonensis. This name was applied to the Sb element; other elements of the apparatus in Bradshaw's collections were left in open nomenclature.

A closely related species, ?Microzarkodina adentata, was described by McTavish (1973). It differs in details of the P element and he considered it to be more closely related to the Periodontidae than the Prioniodontidae. The tentative assignment to Microzarkodina was based on the belief that it may be a very early representative of that genus. Recent authors have followed this practice, although Ethington and Clark (1982) considered it to be a temporary measure until a new genus was erected.

O? marathonensis and ?M. adentata differ markedly from genuine species of Microzarkodina, which have ramiform elements with well-developed, denticulate lateral processes, P elements with a short, denticulate anterior process and M elements without anticusps. The apparatus structure of O? marathonensis is, however, close to that of Oepikodus communis which has an almost identical geniculate coniform M element and a symmetry transition series (Sa - Sc) marked by the position of lateral costae, which are developed into adenticulate lateral processes. The P element differs in being essentially dolabrate rather than having a lateral process. The M element differs from that of O. communis in having a straight, rather than concave, anterior margin to the shorter anticusp, a less inflated basal cavity which does not protrude beyond the general line of the basal margin and a shorter posterior process which may bear a keel on the upper edge.

A new genus is probably necessary to accommodate the differences in the P element and it should include ?M.adentata of McTavish (1973). Until the morphology and apparatuses of other related genera are elucidated the species should be placed within Oepikodus?, as the most closely related genus, rather than in Microzarkodina?

The M element included here in O? marathonensis is very similar to that included by Repetski (1982) but differs significantly from that of Ethington and Clark (1982) who included the element interpreted by Cooper (1981) as the M element of Protoprioniodus yapu Cooper. This element has a high, rounded costa on each face and a strong ridge parallel to the basal margin. It is not present in Greenland faunas. Some degree of affinity with Protoprioniodus does, however, seem likely on the basis of the characteristic flange parallel to the basal margin of the P element but inclusion in that genus is precluded by the denticulate posterior process of O? marathonensis elements.

Range: From 95 m to 204 m in the Wandel Valley Formation in Kronprins Christian Land and 848 - 1010 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 57 P, 26 Sa, 39 Sb, 44 Sc, 54 M.

Oepikodus sp. A.

Pl. 10, Fig. 16

Remarks: A single Sa element has a slightly proclined cusp, a posterior process bearing twelve denticles, a very constricted basal cavity and two, long, adenticulate, postero-laterally directed processes subtending an angle of about 30° with the posterior process. White matter is present in the cusp and along the growth axes of the denticle.

Range: Found at 976 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 1

Oepikodus sp. B.

Pl. 10, Fig. 17

Remarks: The element compares with Sa elements of *Oepikodus*, having symmetrically disposed lateral costae and an erect cusp with anticusp, but differs in that the anticusp and proximal anterior margin are denticulate. The denticles are small, serrate, directed anteriorly, of equal size to those on the posterior process and end at approximately the same level on the cusp.

Range: Found 115 m up the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 1

Genus *OISTODUS* Pander, 1856

1856 *Oistodus* Pander, p. 27

Type Species: *Oistodus lanceolatus* Pander, 1856

Remarks: The apparatus of *O. lanceolatus* is trimembrate, composed of non-geniculate tertiopedate and alate elements and a geniculate element (Bergström, 1981). However, numerous element types have been referred, as form species, to *Oistodus* and are referred below to *Oistodus?*, when the apparatus structure is uncertain or unknown, or as *"Oistodus"*, when used in the form sense.

Oistodus? angulatus Bradshaw, 1969

Pl. 10, Figs 18, 19

* 1969 *Oistodus angulatus*, Bradshaw, p. 1156, pl. 134, Figs 8, 9, text-Fig. 4I.

Description: Upper edge of base very short, sharp. Anterior and posterior margins straight and sharp. Antero-basal angle 20 - 30°, posterior margin upper edge of base 45 - 90°. Outer face flat but with faint median carina. Inner face carinate, base expanded as continuation of carina.

Basal margin straight, basal outline elliptical, widest below carina, pinching out anteriorly and posteriorly. Basal cavity shallow, apex central. Albid in all but base.

Remarks: These characteristic elements occur through a substantial thickness of the Heim Bjerge Formation in very low numbers. No associated elements, which might be part of the same apparatus, were found. The specimens studied by Bradshaw (1969) range slightly lower in the Whiterockian than those from Greenland.

Range: From 331 m above the base to the top of section PF 770713-1 and from 70 to 20 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 9

Oistodus bransoni Ethington and Clark, 1982

Pl. 10, Figs 20, 21

1933 Paltodus jeffersonensis, Branson and Mehl, pl. 4, Fig. 18

1980 "Paltodus" jeffersonensis Branson and Mehl; Kennedy, p. 63, pl. 2, Fig. 1.

* 1982 Oistodus bransoni, Ethington and Clark, p. 65-66, pl. 7, Figs 1-3, 5, 6, text-Fig. 17 (synonomy to 1974)

1982 Oistodus n. sp.; Repetski, p. 32-33, pl. 11, Figs 3, 4, 9, 11, text-Figs 5 - X, Y, Z, A-A

? 1983 Oistodus lanceolatus Pander, Ni in Zeng et al., pl. 11, Fig. 40.

Remarks: The only specimens recovered were of the Sb element and closely resemble that figured by Ethington and Clark (1982, pl. 7,

Fig. 2). O. bransoni is a replacement name for P. jeffersonensis which was figured, but not described, by Branson and Mehl (1933) and subsequently declared a nomen nudum under ICZN article 13a (Kennedy, 1980).

Range: Found at 195 m above the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 2

"Oistodus" triangularis Furnish, 1938

Pl. 10, Fig. 22

* 1933 Oistodus? triangularis, Furnish, p. 330-1, pl. 42, Fig. 22.

1982 "Oistodus" triangularis Furnish, Ethington and Clark, p. 70-1, pl. 7, Figs 15, 18, 22, 23, (synonomy to 1974).

Remarks: Ethington and Clark (1982) included in this species specimens which are laterally compressed with an inturned anterior margin and have one convex and one planar lateral face. The single specimen from Greenland is of this morphology and, in addition, is albid and striate. "O." triangularis has, in the past, been placed in the apparatus of Utahconus? bassleri (Landing and Barnes, 1981; see U? bassleri - Remarks) but due to the small number of specimens recovered here it is considered preferable to keep the two species distinct pending further evidence.

Range: Found 46 m up the Cape Weber Formation on Ella Ø.

Number of Specimens: 1

"Oistodus" sp. nov. A.

Pl. 10, Fig. 23

Description: Geniculate. Upper edge of base short to very short, convex, sharp. Posterior margin sharp proximally, antero-basal angle 90°. Anterior margin curves evenly through 90° or less, narrowly rounded proximally. Cusp strongly laterally compressed near base, width decreases very slowly, distally inflated and of circular cross-section, twisted and deflected inwards in large specimens.

Basal margin slightly concave; basal outline symmetrical, widest anteriorly, narrows rapidly to posterior. Basal cavity small, conical, situated anteriorly, apex near anterior margin.

Hyaline; thickened cusp tip causes characteristic darkening. Keeled upper edge of base albid.

Remarks: The swollen cusp tip renders this element highly characteristic."O." sp. A. was recovered only from the Cape Weber Formation where it is a minor component of high abundance/high diversity faunas. The distinctive morphology is not similar to any previously described elements and there do not appear to be any associated elements of the same apparatus in samples from the Cape Weber Formation.

Range: From 848 m to 976 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 7

"Oistodus" sp. nov. B.

? 1965b *Oistodus linguatus* Lindström; Mound, p. 27-28, pl. 3, Fig. 36.

1965b *Oistodus longiramis* Lindström; Mound, p. 28, pl. 3, Fig. 32.

? 1983 *Oistodus?* sp. nov.; Stouge, pl. 7, Figs 10, 11, 14, 15.

Remarks: All of the specimens recovered are of geniculate coniforms similar to those found in species of *Diaphorodus* and *Oepikodus*, having a short anticusp and slender posterior process. The basal cavity is expanded on the inner face and a faint carina continues on the cusp. One specimen has an inner lateral costa and a more erect cusp. No associated ramiform elements were found.

The specimens are very similar to *O. longiramis* Lindström of Mound (1965b) and have a resemblance to *O?* sp. nov. of Stouge (1983). The latter species was interpreted as having an apparatus of geniculate coniforms with a long posterior process and with or without lateral costae. These elements are robust and hyaline but those from Greenland are slender with albid cusps.

Range: Found at 239 m above the base and at 118 m below the top of the Wandel Valley Formation in central Peary Land and 124 m above the base of PF 770713-1.

Number of Specimens: 5

Genus ONEOTODUS Lindström, 1955

1955 Oneotodus Lindstrom, p. 531

Type Species: Distacodus? simplex (Furnish, 1938)

Remarks: The apparatus of Oneotodus is open to debate. Barnes et al. (1979) considered it to be Type IB or IC, that is, bimembrate with cusp asymmetry defining element types, or unimembrate. Miller (1981) thought it to be an apparatus of acostate to multicostate nongeniculate elements forming a symmetry transition series. Ethington and Brand (1981), in their review of the genus, concluded that the apparatus consisted of elements which varied in cusp cross-section, curvature and costal development. The Greenland material supports this hypothesis but more work on larger collections is needed to determine the exact nature of transitions within the apparatus.

Oneotodus costatus Ethington and Brand, 1981

Pl.11, Figs 1 - 9

1944 Scolopodus n. sp.; Mehl and Ryan in Branson, p. 45, pl. 6, Figs 41-45, (non Figs 46, 47)

1964 Scolopodus cornutiformis Branson and Mehl; Ethington and Clark, p. 698-699, pl. 114, Figs 16, 23.

* 1981 Oneotodus costatus, Ethington and Brand, p. 242-245, text-Figs 1 B, D, G, H, 2 A, D-M (Synonomy to 1979).

1982 Oneotodus aff. simplex (Furnish), Ethington and Clark, p. 73-74, pl. 8, Fig. 7.

1982 Scolopodus abruptus, Repetski, p. 45-46, pl. 21, Figs 1, 3, text-Fig. 7K.

1982 Oneotodus costatus Ethington and Brand, Stouge, p. 41, pl. 2, Figs 18, 19, 25.

Remarks: For several years, O. costatus was commonly misidentified as Scolopodus cornutiformis Branson and Mehl, until the mistake was noted by Ethington and Brand (1981). O. costatus differs from S. cornutiformis in being albid and circular in cross-section. A considerable variation in morphology is present within the species. The costae from which the species takes its name vary from being closely spaced, low and rounded to widely spaced and prominent with the anterior face of each costa aligned at a low angle to the cusp and the posterior face almost normal to the cusp. Costae are present only on lateral and posterior faces of strongly costate forms but may be present, though faint, on the anterior face of specimens with costae of low relief.

The curvature of the cusp is also variable although the majority of specimens are reclined at approximately 30 - 40° to the plane of the basal margin. The basal cavity is of more consistent morphology, having a short, steep anterior margin and a long gently sloping posterior margin. Both of these margins are straight. The apex of the cavity is situated anteriorly, beneath the main part of the cusp. The basal outline is more or less ovate.

Ethington and Clark (1982) mentioned that some of their elements have regenerated cusps. Such specimens are more recurved, have short cusps, often of reduced diameter, and were interpreted by Ethington and Brand (1981) as normal elemental variations. The extreme variants of this type from Greenland come close to the morphology of Weberina guyi gen. et sp. nov., to which O. costatus may be closely related.

Range: From the base to 147 m in the Wandel Valley Formation of Peary Land and from the base to 205 m in the Wandel Valley Formation of Kronprins Christian Land. O. costatus has a range of 150 - 880 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 190

"Oneotodus" mitra Abaimova, 1971

Pl. 11, Fig. 10

* 1971 Oneotodus mitra, Abaimova, p. 80-81, pl. 10, Fig. 12.

1975 Oneotodus mitra Abaimova; Abaimova, p. 82-83, pl. 7, Figs 4, 7, text-Figs 7, 16-18, 21-24.

Remarks: The specimens are comparable with the figured specimens of Abaimova (1971, 1975) in having a very flared base surmounted by an extremely small cusp. One specimen has a lower, wider base than those figured by Abaimova.

Range: Found 4 m up the Wandel Valley Formation in Børglum Elv and at 306 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 2

Oneotodus sp. A.

Pl. 11, Fig. 11, 12

Remarks: The upper edge of the base is short and rounded, curving sharply around into the erect to reclined cusp, which is antero-posteriorly compressed. The anterior face is rounded and faintly costate. The posterior face is broadly rounded with multiple, low, rounded costae. The basal margin is straight, the basal outline is sub-triangular to circular. The base is very flared and the basal cavity is fairly shallow and conical with an apex close to the anterior margin. The cusp is albid.

The element is grossly similar to *O. costatus* but differs in having an antero-posteriorly compressed cusp and a more flared base.

Range: Found at 45 m in the Wandel Valley Formation in Kronprins Christian Land and at 454 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 3

Genus _OULODUS_ Branson and Mehl, 1933

1933 _Oulodus_ Branson and Mehl, p. 116

1935a _Gyrognathus_ Stauffer, p. 144

1935b _Barbarodina_ Stauffer, p. 602-603

1971 _Delotaxis_ Klapper and Philip, p. 446

Type Species: _Cordylodus_ _serratus_ Stauffer, 1930.

Oulodus? sp. nov. A.

Pl. 11, Figs 13 - 16

? 1982 _?Plectodina_ sp.; Ethington and Clark, p. 82, pl. 9, Figs 8, 9, 13.

Remarks: Four elements of the apparatus were recovered. The Pa and Pb elements are digyrate, the Sc element is bipennate with a single anterior denticle and there is a digyrate Sb element. The Pa element has denticles on the posterior process which are laterally compressed, discrete and reclined; those on the anterior process are of similar morphology but erect. The Pb element is robust, with a shallow, broadly-excavated basal cavity. The denticles are erect and less compressed than those on the Pa element. The cusp is erect to reclined and twisted towards the longer of the two processes.

The Sc element has a single, antero-lateral, denticle. The denticles on the posterior process are reclined and discrete but closely spaced. The digyrate Sb is distinguished from the Pb in being less robust and having a basal cavity confined to the base of the cusp. All elements have white matter confined to the cusp and denticles.

The species has been described from the Bay Fiord Formation of Arctic Canada by Nowlan (1976) and the larger collections include an alate Sa element. Nowlan proposed that the M position in the apparatus was filled by elements similar to the Sc but lacking the antero-lateral denticle.

The fragmentary specimens described as _?Plectodina_ sp. by Ethington and Clark (1982) may be conspecific with _O?_ sp. A.

Range: Found at 286 m above the base of the Wandel Valley Formation in central Peary Land and from a clast in the Devonian basal conglomerate on C.H. Ostenfeld Nunatak.

Number of Specimens: 5 Pa, 5 Pb, 6 Sc, 6 Sb.

Genus PANDERODUS Ethington, 1959

1959 Panderodus Ethington, p. 284

Type Species: Paltodus unicostatus Branson and Mehl, 1933.

Remarks: Many apparatus reconstructions have been advanced for species of Panderodus. The number of elements included varies from two (Bergström and Sweet, 1966; Barnes et al., 1979) to four (Barrick, 1977) or five (Sweet, 1979). It has even been suggested by Nowlan and Barnes (1981) that the genus encompasses three apparatus styles; one in accordance with the models of Barrick (1977) and Sweet (1979) and the other two bimembrate.

Jeppsson (1983) is in the process of a complete revision of the genus and, as a consequence, Panderodus is here discussed only very briefly. The elements are referred to two broad groups, compressed (falciform of Sweet, 1979) and costate. The latter group includes a large range of symmetrical to asymmetrical and proclined to erect transitions which have been sub-divided by other authors (Barrick, 1977; Sweet, 1979).

Panderodus aff. panderi (Stauffer)

Pl. 11, Figs 17 - 23

aff. 1940 Paltodus panderi, Stauffer, p. 427, pl. 60, Figs 8, 9.

aff. 1979 Panderodus panderi (Stauffer); Sweet, p. 64-5, pl. 7, Figs 2-6, 10.

Remarks: The elements here included in *P.* aff. *panderi* may represent a new species and very similar elements were considered as such by Nowlan (1976) in an unpublished PhD thesis. However, I consider it premature to erect a new species of *Panderodus* prior to the imminent revision of the genus.

The costate group of elements are characteristic in having a large proportion of elements with a prominent, sharp, antero-lateral costa and a flat, lateral face posterior to it. Some of the symmetrical costate elements have extremely long bases and much reduced cusps with subdued costae.

Range: From 38 m below the top of the Wandel Valley Formation into the Børglum River Formation in Peary Land. A sample 33 m up the un-named formation contains *P.* aff. *panderi* and it continues through into the Børglum River Formation in Kronprins Christian Land. From 278 m above the base of PF 770713-1 to the top of the section on Albert Heim Bjerge and throughout the upper 100 m of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Number of Specimens: 273 compressed, 447 costate.

Genus PARAPRIONIODUS Ethington and Clark, 1982

1982 Paraprioniodus Ethington and Clark, p. 77

Type Species: Tetraprioniodus costatus Mound, 1965b.

Paraprioniodus costatus (Mound, 1965b)

Pl. 12, Figs 1 - 11

*	1965b	Tetraprioniodus costatus, Mound, p. 34-5, pl. 4, Figs 19, 25, 31, text-Fig. 1K.
	1974	Hyaline prioniodiform elements; Barnes, pl. 1, Fig. 14.
?	1977	"Eoneoprioniodus" sp.; Barnes, p. 102, pl. 2, Figs 1, 2.
non	1978	Cordylodus sp. A.; Tipnis, Chatterton and Ludvigsen, pl. 4, Fig. 22.
	1982	Paraprioniodus costatus (Mound); Ethington and Clark, p. 77-79, pl. 8, Figs 20-26, (synonomy to 1979)
	1982	Paraprioniodus costatus (Mound); Rexroad, Droste and Ethington, p. 9, pl. 1, Figs 7-20, 22-26, text-Fig. 7.
	1982	Eoneoprioniodus? sp.; Stouge, pl. 7, Figs 15, 19.
	1983	Eoneoprioniodus? sp. A; Stouge, pl. 5, Figs 1-4, 7.

Remarks: The apparatus of P. costatus has been described and discussed by Ethington and Clark (1982) and Rexroad, Droste and Ethington (1982). The apparatus is complex and is characterised by very fluid transitions between element types and a large amount of intra-elemental variation. In the Greenland material, the apparatus of P. costatus is interpreted to consist of six basic element types; pastinate bipennate, two types of dolabrate, alate and quadriramate. All have bar-shaped processes and discrete, albid, peg-like denticles.

The pastinate element probably occupies the Pa position and can be sub-divided into three types. The smallest has a short, erect to reclined cusp with a costa running down the anterior face. At the base of the cusp, an antero-laterally directed process connects with the costa. The element was figured as Dichognathus extensa Branson and Mehl by Mound (1965b) and corresponds to the extended prioniodiform element of Ethington and Clark (1982).

The second type of pastinate element is more arched and the cusp is produced antero-basally as a process bearing up to five denticles. This is the pendent prioniodiform element of Ethington and Clark (1982). The third type of pastinate element is rare (only 7 out of 126 specimens) and is probably the gerontic extended prioniodiform element mentioned by Ethington and Clark (1982). The cusp is reduced in height and is broad. The basal cavity is large and shallow, extending as broad shallow troughs beneath the processes.

The two types of "prioniodiform" element described by Ethington and Clark (1982) are actually part of a fairly fluid transition within the Pa element and the three forms are here treated as variants of a single element position. The transition may be ontogenetic, although there is no firm evidence for this.

The bipennate element has an anterior process which is directed antero-basally and bears up to four denticles. The basal cavity is sub-circular in outline and shallow. In large specimens it may extend as shallow troughs beneath the processes. The cusp is broadly rounded on its outer face but more convex on the inner and is, additionally, strongly deflected inwards. The bipennate element is interpreted as occupying the Pb position and shows a transitional relationship with the M element.

The dolabrate M element was described as cyrtoniodiform by Ethington and Clark (1982). The cusp is carinate and deflected inwards and the basal cavity is flared on the inner side. The rather similar dolabrate Sc element differs in having a cusp which is in the plane of the posterior process, a symmetrical basal cavity and denticles which are more widely spaced, erect and peg-like. The element may possess a sub-quadrate anticusp or a short, compressed anterior process bearing up to three small denticles. The Sc is, by far, the most common element of the apparatus.

The Sa element is alate, although rarely the posterior process may be offset from the plane of symmetry, creating an element of more tertiopedate symmetry. There is no element of typical Sb morphology but it is possible that the quadriramate element occupies an Sb rather than an Sd position since the "fourth process" is an anticusp. The quadriramate element has a posterior process, a second directed postero-laterally, another basally and the fourth is the anticusp. The posterior and postero-lateral processes are denticulate, the antero-lateral process is usually adenticulate, but some specimens do bear up to three denticles, and the anticusp is adenticulate.

It was noted by Ethington and Clark (1982), with particular reference to the Sc element, that the keels on the cusp may be albid, with prismatic structures aligned normal to the cusp edge. This feature is not common in Greenland material but the bipennate elements of one sample (GGU 271662) show a development of small, serrate denticles running along the proximal part of the anterior margin as a continuation of the anterior process. (Pl. 12, Fig. 11)

In summary, the apparatus of P. costatus is seximembrate, consisting of a Pa element with three (?ontogenetic) morphotypes, a bipennate Pb, a dolabrate M, a dolabrate Sc which may develop a denticulate anticusp, an alate Sa and a quadriramate element which occupies the Sb, or possibly Sd position. The transition from Pa - Pb - M - Sc is very smooth and some intermediate elements may be difficult to classify. The principal difference between this reconstruction and that of Rexroad et al. (1982) is that they considered both their cordylodiform (Sc) and cyrtoniodiform (M) elements to show dolabrate to bipennate transitions. In Greenland faunas, the Sc elements do show this transition but only dolabrate M elements are found, despite the large faunas.

Range: From 115 m to 80 m below the top of the Wandel Valley Formation in western Peary Land. In central Peary Land it occurs 221 m to 239 m above the base of the Wandel Valley Formation (JEM 790627-1) and 118 m to 96 m below the top (JEM 790701-1). From 36 m to 258 m above the base of PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 126 Pa, 26 Pb, 54 M, 173 Sc, 52 Sa, 102 Sb/Sd.

Genus PHRAGMODUS Branson and Mehl, 1933

1933 Phragmodus Branson and Mehl, p. 98

? 1933 Dichognathus Branson and Mehl, p. 35

? 1935a Cyrtoniodus Stauffer, p. 140

? 1935a Subcordylodus Stauffer, p. 153

Type Species: Phragmodus primus Branson and Mehl, 1933.

Remarks: The apparatuses of most species of Phragmodus contain two types of P element, one being pastinate or angulate and the second being pastinate (Barnes et al., 1979; Bergström, 1981). In contrast, P. flexuosus bears a single pastinate P element and Harris et al. (1979) showed that the apparatus of the slightly younger P. sp. nov. A. similarly contains only a single P element. Both of these species may precede the divergence of morphologies within the P positions in Phragmodus.

A second difference in the apparatus of P. flexuosus is the presence of a geniculate coniform M element whereas P. sp. nov. A. and younger species have a dolabrate M element. The youngest species of Phragmodus (for example P. undatus Branson and Mehl) do, however, revert to a coniform M element.

Neither of these apparatus variations are considered sufficient to exclude either P. flexuosus or P. sp. nov. A. from Phragmodus.

Phragmodus flexuosus Moskalenko, 1973

Pl. 12, Figs 12 - 17, 24

* 1973	Phragmodus flexuosus, Moskolenko, p. 73-4, pl. 11, Figs 4-6.
1973	Gothodus evengiensis, Moskalenko, p. 67-8, pl. 11, Figs 1-3a, b.
? 1975	Oistodus subabundens, Nasedkina, p. 119, pl. 6, Figs 1, 2.
? 1975	Phragmodus borealis, Nasedkina, p. 124-5, pl. 6, Figs 13, 14.
non 1978	Phragmodus flexuosus flexuosus Moskalenko; Tipnis, Chatterton and Ludvigsen, pl. 5, Figs 1, 2, 4.
non 1978	Phragmodus flexuosus symmetricus, Tipnis, Chatterton and Ludvigsen, p. 60-1, pl. 5, Figs 6-9.
non 1979	Phragmodus flexuosus Moskalenko; Harris et al., pl. 2, Figs 1-4.
1982	?Phragmodus flexuosus Moskalenko; Ethington and Clark, p. 79-82, pl. 9, Figs 2-7, (synonomy to 1979).
1982	Phragmodus flexuosus Moskalenko; Moskalenko, p. 129, pl. 30, Figs 1-5, text-Fig. 9-1.

Remarks: The elements here assigned to P. flexuosus are identical to those described by Ethington and Clark (1982) as ?P. flexuosus, consisting of a pastinate P element, a geniculate coniform M element and Sa - Sd elements with long posterior processes. Symmetry transition is expressed by the position of costae on both the cusp and basal cavity. Sa, Sb and Sd elements have sinuous posterior processes with phragmodiform denticulation but the Sc element has an unflexed process with more even-sized, reclined denticles. The elements were thoroughly described by Ethington and Clark (1982).

Phragmodus flexuosus of Harris et al. (1979) differs from the above apparatus in having a dolabrate, denticulate M element, all other elements being similar. These two apparatuses, here considered to be distinct species, have been reported to occur in stratigraphic succession, the species with the coniform M element being the older of the two (Ethington and Clark, 1982).

A problem arises in deciding to which of the two species the name P. flexuosus is applicable. Elements of this morphology were first described from the Siberian Platform by Moskalenko (1970) and subsequently reconstructed by her as a nine element apparatus (Moskalenko, 1972). The Pa and phragmodiform (Sa, Sb and Sd) elements were later named in form taxonomy by Moskalenko (1973) and the remaining elements were assigned to existing form taxa. A geniculate coniform was described together with these elements, but Ethington and Clark (1982) considered that specimens described as Plectodina glenwoodensis, from the same sample, by Moskalenko (1973) were dolabrate M elements. Since the only diagnostic element is the M, Ethington and Clark (1982) concluded that the problem was insoluble without reference to Siberian material but tentatively applied the name to the apparatus containing the coniform M element. Additionally, Moskalenko (1982) included only a geniculate coniform in the apparatus of P. flexuosus and the specimens referred to as Plectodina glenwoodensis by Moskalenko (1973) may be broken P elements. This reconstruction is followed here and P. flexuosus is applied to the coniform-bearing apparatus. The apparatus with a dolabrate M element is described as P. sp. nov. A.

Range: Found at 286 m above the base and 81 m to 58 m below the top of the Wandel Valley Formation in central Peary Land and 8 m above the base of the new, un-named formation in Kronprins Christian Land. Found 288 m above the base of section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 46 P, 125 M, 21 Sa, 17 Sb, 70 Sc, 30 Sd.

Phragmodus sp. nov. A.

Pl. 12, Figs 18, 19

1971 Phragmodus sp. A.; Sweet, Ethington and Barnes, pl. 2, Figs 3-6.

1978 Dichognathus sp.; Tipnis, Chatterton and Ludvigsen, pl. 5, Fig. 3.

1978 Phragmodus flexuosus flexuosus Moskalenko; Tipnis, Chatterton and Ludvigsen, pl. 5, Figs 1, 2, 4.

? 1978 Phragmodus flexuosus symmetricus, Tipnis, Chatterton and Ludvigsen, p. 60-1, pl. 5, Figs 6-9.

1979 Phragmodus flexuosus Moskalenko; Harris et al., pl. 2, Figs 1-4.

1981 *Phragmodus flexuosus* Moskalenko; Sweet *in* Klapper *et al.* p. 255-8, *Phragmodus*, pl. 2, Figs 1-6.

Remarks: Two dolabrate M elements and an Sc element were recovered from the Wandel Valley Formation of central Peary Land, and are comparable with the figured specimens of Harris *et al.* (1979)

Range: Found at 17 m below the top of the Wandel Valley Formation in central Peary Land.

Number of Specimens: 2 M, 1 Sc.

Phragmodus sp.

Remarks: A few specimens of a *Phragmodus* apparatus with *P. flexuosus*-like ramiform elements were recovered from the Wandel Valley Formation. No M elements were recovered and the apparatus could not, therefore, be assigned to a species.

Range: Found 38 m below the top of the Wandel Valley Formation in central Peary Land.

Number of Specimens: 2 P, 2 Sa, 2 Sb, 3 Sc.

Genus *PLECTODINA* Stauffer, 1935a

1935a *Plectodina* Stauffer, p. 152.

1948 *Trichonodella* Branson and Mehl (*nom. subst. pro. Trichonognathus* Branson and Mehl, 1933), p. 527.

1951 *Eoligonodina* Branson, Mehl and Branson, p. 14-15.

? 1951 *Zygognathus* Branson, Mehl and Branson, p. 11.

Type Species: *Prioniodus aculeatus* Stauffer, 1930.

Plectodina? sp. A.

Pl. 12, Figs 20 - 23

Remarks: Only three of the elements of the apparatus were recovered and most specimens are fragmentary. The Pa element is angulate with a short anterior process bearing up to two denticles and a posterior process with erect, discrete denticles. The denticles and cusp are strongly laterally compressed. The Sc element is dolabrate with an anticusp and a sharp anterior margin deflected inwards. The denticles on the posterior process are reclined and vary from being confluent at the bases to discrete. The Sb element is digyrate, one lateral process consisting of a single, tall, strongly laterally compressed denticle. The opposite lateral process is postero-laterally directed and bears up to three discrete denticles. White matter is present in the cusp and denticles.

Range: From 49 to 3 m below the top of the Wandel Valley Formation in Central Peary Land.

Number of Specimens: 5 Pa, 5 Sb, 14 Sc.

Genus PROTOPANDERODUS Lindström, 1971

1971 Protopanderodus Lindström, p. 50

Type Species: Acontiodus rectus Lindström, 1955

Protopanderodus elongatus Serpagli, 1974

Pl. 13, Figs 1 - 3

* 1974 Protopanderodus elongatus, Serpagli, p. 73-75, pl. 16, Figs 8a-11c, pl. 25, Figs 13-16, pl. 30, Fig. 4, text-Fig. 16 (synonomy to 1974)

1982 Protopanderodus elongatus Serpagli, Ethington and Clark, p. 84, pl. 9, Fig. 15.

1982 Protopanderodus elongatus Serpagli, Repetski, p. 39, pl. 16, Figs 4, 5, 7, 9, 11, 12, text-Fig. 6T.

Remarks: The specimens at hand compare closely with Serpagli's (1974) description and all of the element types mentioned by him (acostate, unicostate and bicostate) are present. The Greenland specimens are very small, albid in all except the basal region and strongly laterally compressed. The anterior margin is blunt, becoming sharper distally. The element types are intergradatory and the costae vary in position on the lateral faces, being symmetrical, and placed anteriorly or posteriorly, or asymmetrical.

Range: 438 - 992 m in the Cape Weber Formation on Ella Ø and at 200 m above the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 44

Protopanderodus gradatus Serpagli, 1974

Pl. 13, Figs 4 - 12

? 1967 Paltodus variabilis Furnish; Higgins, text-Fig. 2.7.

* 1976 Protopanderodus gradatus, Serpagli, p. 75-77, pl. 15, Figs 5a-8b, pl. 26, Figs 1a, b, text-Fig. 17.

1976 Protopanderodus gradatus Serpagli; Landing, p. 637, pl. 4, Figs 8, 9, 11, 12.

1982 Protopanderodus gradatus Serpagli; Ethington and Clark, p. 84-85, pl. 9, Figs 16, 17, 20, 21, (synonomy to 1981)

1982 Protopanderodus gradatus Serpagli; Repetski, p. 39, pl. 17, Figs 1-5, text-Figs 6 U, Z, AA.

? 1982 Protopanderodus cf. P. gradatus Serpagli; Repetski, p. 39, Figs 6a-7c, text-Fig. 6W.

Remarks: P. gradatus from Greenland is closely similar to the San Juan material of Serpagli (1974). In his description he mentions that the transition from "Scandodus"-like specimens to "Scolopodus"-like specimens is incomplete. Elements were described by Ethington and Clark (1982) which are transitional between the two end members and similar elements have been found in the Cape Weber Formation. They are similar to the element figured third from the left in Serpagli's text-fig. 17 but have a lateral groove on the opposite face to the antero-lateral groove. This lateral groove is very close to the posterior margin.

A rare component of the apparatus is a short-based, erect element which has an untwisted laterally-grooved cusp of lenticular cross-section.

Repetski (1982) included some acostate, laterally compressed elements within P. gradatus. These were not found in the Cape Weber Formation although Repetski's collection is larger than mine.

Range: From 438 to 992 m in the Cape Weber Formation on Ella Ø and from 95 to 155 m in the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 110

Protopanderodus cf. gradatus Serpagli, 1974

Pl. 13, Fig. 15

Remarks: A few specimens from the Wandel Valley Formation in Peary Land are very similar in morphology to the scandodiform element of P. gradatus. However, since the characteristic, and usually more abundant, intermediate and scolopodiform elements have not been recovered from Peary Land these elements are only questionably included in P. gradatus.

Range: 30 - 46 m above the base of the Wandel Valley Formation in central Peary Land.

Number of Specimens: 4

Protopanderodus leonardii Serpagli, 1974

Pl. 13, Figs 13, 14

* 1974 Protopanderodus leonardii, Serpagli, p. 77-79, pl. 16, Figs 1a-4c, pl. 27, Figs 12-16, text-Fig. 78.

1978 Protopanderodus cf. P. rectus (Lindström); Tipnis et al., pl. 3, Fig. 28.

1982 Protopanderodus leonardii Serpagli; Ethington and Clark, p. 85, pl. 9, Figs 18, 22, 23, (synonomy to 1981).

1982 Protopanderodus leonardii Serpagli; Repetski, p. 39, pl. 16, Figs 4, 5, 7, 9, 11, 12, text-Fig. 6T.

Remarks: Nearly all of the Greenland specimens are of the bilaterally symmetrical element. No associated "scandodiforms" were found and hence part of the Protopanderodus apparatus is missing. The overall morphology of P. leonardii is closely similar to that of P. gradatus. The basal cavity, curvature, general size and white matter distribution are comparable and Ethington and Clark (1982) suggested that the two are conspecific, with P. leonardii being the truly symmetrical member of the apparatus. This would result in an apparatus more closely similar to that of P. rectus, the type species, consisting of twisted asymmetrical elements, grooved sub-symmetrical elements and symmetrical elements (van Wamel, 1974). Ethington and Clark (1982) noted, however, a discrepancy in the two ranges in the Ibex area and refrained from combining the two species until further studies resolved the problem. P. leonardii does occur below P. gradatus on Ella Ø although only a few specimens are involved. Additionally, in Kronprins Christian Land, P. leonardii occurs with no associated P. gradatus. The paucity of material from Greenland, though, precludes a meaningful contribution to the problem.

Range: From 342 to 1140 m in the Cape Weber Formation on Ella Ø and from 95 to 200 m above the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 52

Genus PROTOPRIONIODUS McTavish, 1973

1965 New genus and species, Ethington and Clark, p. 203

1971 New genus A Sweet, Ethington and Barnes, pl. 1, Figs 19, 22

1973 Protoprioniodus McTavish, p. 47

1974 Gen. nov. B. Serpagli, p. 93

Type Species: Protoprioniodus simplicissimus McTavish, 1973

Remarks: The apparatus of Protoprioniodus was included within Type IIB by Barnes et al. (1979), who interpreted it as a simple transition series with no associated elements, the geniculate coniform element (oistodiform) being included in the transition series. Bergström (1981) reached a similar conclusion and placed the genus within the Oistodontidae. The recognition that the apparatus includes adenticulate platform elements (Cooper, 1981; Ethington and Clark, 1982) means that it is more like a Type IVD, with a ramiform transition series Sa - Sc, an oistodiform M and an adenticulate, platform-like P element, the latter occuring in the apparatus in low numbers. The nearest relations of the genus are probably in the Prioniodontacea.

Protoprioniodus aranda Cooper, 1981

Pl. 13, Fig. 16

* 1981 Protoprioniodus aranda, Cooper, p. 175-76, pl. 30, Figs 1, 6, 7, 10, 12

? 1981 Protoprioniodus nyinti, Cooper, p. 176-78, pl. 29, Figs 1-8, 11, 12

1982 Protoprioniodus aranda, Cooper; Ethington and Clark, p. 86-87, pl. 9, Figs 24-30, (synonomy to 1981)

1982 New Genus A Sweet and others, 1971; Repetski, p. 56-57, pl. 27, Figs 1-6

1982 Protoprioniodus n. sp. A; Stouge, p. 42, pl. 5, Figs 5-7

1982 Protoprioniodus sp. A; Stouge, pl. 4, Figs 5, 8

Remarks: A single oistodiform element was recovered from the Wandel Valley Formation. It most resembles those figured by Ethington and Clark (1982, pl. 9, Fig. 30) and Stouge (1982, pl. 5, Fig. 7).

Range: Found 260 m above the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 1

Protoprioniodus papiliosus (van Wamel, 1974)

Pl. 13, Figs 17 - 23

p* 1974 Oistodus papiliosus, van Wamel, p. 76-77, pl. 1, Fig. 19a, b only (non pl. 19, Figs 18, 20).

1974 Gen. nov. B n. sp. 1, Serpagli, p. 93, pl. 19, Figs 4a, b, pl. 29, Figs 4, 5, text-Fig. 26

1982 Protoprioniodus papiliosus (van Wamel); Ethington and Clark, p. 37-88, pl. 10, Fig. 5

Description:

Ramiform elements

Cusp erect with posterior keel and antero-lateral costae. Costae blade-like, extended as adenticulate processes, symmetry transition defined by relative positions of these costae. On the Sa they are directed slightly posteriorly giving rounded anterior face on which low medial costa is developed. Sb has one costa in or near plane of posterior process, other roughly at right angles, directed antero-laterally; cusp slightly twisted relative to posterior process. The Sc has the costae directed antero-laterally creating an anterior face with median furrow, cusp again slightly twisted.

Posterior process bears high, thin blade, triangular in profile. Posterior edge slopes down evenly, or may be slightly concave, until it meets a flange at 90°. Flange characteristic of Protoprioniodus, running parallel to basal margin, present on all processes and runs across anterior face. Angle between posterior process and antero-lateral processes varied from almost 90° to approximately 30° (in the Sa). Basal cavity shallow and very constricted.

Coniform element

Geniculate, cusp reclined, ½ longer than base. Posterior margin sharp. Anterior margin sharp and deflected by up to 90° above the basal flange. Lateral faces flat. Antero-basal angle 20°, postero-basal angle approximately 20°. Upper edge of base short.

Basal cavity very narrow, very shallow, low apex situated anteriorly. Basal margin straight or very slightly concave anteriorly. Basal flange may be absent or weakly developed in some specimens.

All elements entirely albid above flange and hyaline below it, flange forming a sharp junction. In geniculate coniform, flange is absent but there is still a sharp junction parallel to the basal margin at the same height.

Remarks: The adenticulate platform element postulated to occur in species of Protoprioniodus by Cooper (1981) and Ethington and Clark (1982) has not been recovered from Greenland. This is perhaps not surprising considering the approximately 8:1 ratio of ramiforms: platforms (Ethington and Clark, 1982) and the small collection at hand.

P. papiliosus was originally placed in Oistodus by van Wamel (1974) but is albid, unlike true species of Oistodus. The "deltaform" and geniculate elements figured by van Wamel (1974, pl. 1, Figs 18, 20) were not recovered by Ethington and Clark (1982) and do not occur in the Greenland collections. The apparatus does not conform to that of Oistodus but as the holotype of the species in the "triangulariform" element, his specific name is applicable.

Ethington and Clark (1982) thought that their specimens comparable with the holotype should be placed in Protoprioniodus and speculated that they may be rare components of the P. aranda Cooper apparatus. The discovery of an associated oistodiform of different morphology to that in P. aranda indicated that P. papiliosus is a distinct species. The elements have a typical Protoprioniodus morphology, possessing the flange parallel to the basal margin, being albid above the flange and having a blade-like keel on the posterior process. The basal cavity is also consistent with this assignment in being narrow and shallow.

The most similar species of Protoprioniodus is P. aranda, of which P. papiliosus may well be the ancestor. P. papiliosus differs in having a more slender, unflexed geniculate coniform with no lateral carina. The anterior margin of the cusp is deflected and the basal margin is straight. The ramiforms have a characteristic triangular keel on the posterior process.

Range: The species ranges from 55 m to 200 m in the Wandel Valley Formation of Kronprins Christian Land and from 848 m to 992 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 10 ramiforms, 8 oistodiforms.

Protoprioniodus sp.

Remarks: Two fragmentary specimens have the characteristic basal flange, lateral costae and white matter distribution of Protoprioniodus but the fragmentary nature of the material precludes specific assignment.

Range: Found 1161 m above the base of the Cape Weber Formation on Ella Ø.

Number of Specimens: 2

Genus *PSEUDOONEOTODUS* Drygant, 1974

1974 *Pseudooneotodus* Drygant, p. 66

Type Species: *Oneotodus? beckmanni* Bischoff and Sannemann, 1958

Pseudooneotodus sp.

Pl. 13, Fig. 24

Remarks: A single specimen was recovered from the Heim Bjerge. The specimen bears only a single denticle tip at the apex.

Range: Found at 489 m above the base of section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 1

Genus PTERACONTIODUS Harris and Harris, 1965

1965 Pteracontiodus Harris and Harris, p. 41

1965a Eoneoprioniodus Mound, p. 195

Type Species: Pteracontiodus aquilatus Harris and Harris, 1965

Remarks: Bergström (1981) considered Trigonodus Nieper and Triangulodus van Wamel to be junior synonyms of Eoneoprioniodus Mound and Pteracontiodus to be a closely related species with unknown apparatus structure. Triangulodus was erected by van Wamel (1974) to include species differentiated from Scandodus on the basis of their seximembrate apparatus, as opposed to the trimembrate apparatus of Scandodus; Oistodus brevibasis Sergeeva, 1963 was selected as the type species. Löfgren (1978), however, agreed with Lindström (1971) and reassigned van Wamel's (1974) type species to Scandodus although Lindström (1977) assigned the species to Pteracontiodus.

Cooper (1981) reconstructed the apparatus of Trigonodus larapintinensis (Crespin) and amended the diagnosis to include hyaline elements forming a seximembrate apparatus with an Sa - Sd transition series marked by the varying distribution of costae, a coniform P element and a geniculate M element. Cooper considered this genus to be a senior synonym of Triangulodus and also included T. akpatokensis (Barnes, 1976).

The confusion was clarified somewhat by Ethington and Clark (1982) who reserved Pteracontiodus for hyaline species with an Sa - Sd transition series, where the costae are produced basally as adenticulate processes, and a geniculate coniform M element. Eoneoprioniodus was recognised as a junior synonym.

I consider that a combination of the conclusions of Cooper (1981) and Ethington and Clark (1982) is the best solution to the overall problem. Trigonodus would thus include hyaline species with an Sa - Sd transition series, "P" and M elements and have Triangulodus as a junior synonym. Pteracontiodus, with Eoneoprioniodus as a junior synonym, has essentially the same apparatus but lacks a "P" element and has the costae produced as adenticulate processes (Ethington and Clark, 1982). Scandodus is reserved for hyaline, trimembrate apparatuses consisting of a transition series of one geniculate and two non-geniculate coniform elements (Bergström, 1981). Albid species with apparatus broadly similar to Pteracontiodus are included in Tripodus Bradshaw (emended Ethington and Clark, 1982) or Diaphorodus Kennedy.

The species here considered to belong in Pteracontiodus are P. aquilatus Harris and Harris, P. cryptodens (Mound), P. alatus (Dzik), P. gracilis (Ethington and Clark) and P. armillatus sp. nov.

Pteracontiodus armillatus sp. nov.

Pl. 13, Figs 25 - 38

Diagnosis: Apparatus quinquimembrate consisting of an Sa - Sd transition series and a geniculate coniform M. All elements have a low, rounded ridge on the base parallel to the basal margin.

Derivation of Name: armillatus (L.), ornamented with a bracelet; with reference to the prominent ridge parallel to the basal margin.

Description:

Sa element

Upper edge of base sharp, short, curving evenly into erect cusp. Posterior margin sharp, gently curved throughout length. Anterior face broadly rounded, tapering evenly, may be depressed centrally at antero-basal corner. Antero-lateral costae sharp, evenly curved throughout length. Postero-lateral faces concave. Posterior margin a broad carina, may bear a keel.

Basal outline triangular. Basal margin straight to arched anteriorly, concave postero-laterally. Cavity moderately deep, opens to posterior, apex anterior.

Sb element

Upper edge of base short, keeled, meets reclined to recurved cusp at acute angle. Posterior margin sharp, gently curved for most of length, straight distally. Anterior margin bears low, narrow, sharp keel, gently curved throughout length. Inner face flat anteriorly, curving round to meet posterior margin. Outer face bears sharp costae, produced as adenticulate process basally, directed antero-basally. Antero-lateral outer face concave. Postero-lateral outer face flat or slightly convex, a groove may be present adjacent to cusp-base junction. Cusp cross-section triangular in all but very mature specimens.

Basal margin markedly convex. Basal outline approximately triangular. Basal cavity shallow, opens to posterior. Apex central or just anterior.

Sc element

Upper edge of base very short, keeled, meeting recurved cusp at an acute angle. Posterior margin sharp, convex proximally, straight distally. Anterior margin regularly curved proximally, straight distally. Cusp strongly laterally compressed. Outer face convex, may bear a very low median carina. Inner face broadly convex, may bear a carina, if so there is a groove between the carina and anterior margin; cusp may be deflected inwards.

Basal margin strongly convex. Basal outline lenticular, compressed anteriorly, swollen medially, open to posterior. Apex situated at maximum cavity width or just anterior.

Sd element

Upper edge of base short, keeled, meeting reclined cusp at acute angle. Posterior margin sharp, gently curved proximally, straight distally. Anterior margin sharp, regularly curved in proximal two-thirds, straight in distal one-third, produced basally as adenticulate anticusp deflected inwards, anterior margin of process at 70° to upper edge of base. Inner face bears sharp costa produced basally as postero-laterally directed process. Costa triangular in cross-section. Deep v-shaped groove between costa and anterior margin, shallower groove between costa and posterior margin. Outer face has sharp costa produced basally as adenticulate process. Outer antero-lateral face concave; outer postero-lateral face flat, may have posterior carina with shallow groove just anterior to it.

Basal outline quadrate, basal cavity directed posteriorly, apex anterior.

M element

Upper edge of base short, keeled, meeting cusp at acute angle. Posterior margin sharp, evenly curved throughout length. Anterior margin sharp, gently curved throughout length. Cusp tapers rapidly to fine point. Inner and outer faces gently convex, inner face with median carina. Antero-basal angle 30°; postero-basal angle 30°.

Basal margin straight except at base of carinae where it is convex. Basal cavity inflated at base of carinae, narrow and slit-like anterior and posterior, flares more inwards. Element grades into Sc element morphology to some extent.

All elements are finely striate, hyaline with a thin growth axis and have a nicked margin at a junction between posterior margin and upper edge of base. A low, rounded ridge runs parallel to basal margin a short distance above it.

Remarks: Elements of *P. armillatus* are characterised by having a ridge running parallel to the basal margin and in the morphology of the adenticulate processes. The species most resembles *P. alatus* (Dzik), an upper Llanvirn species, but differs in having a less well-developed posterior process on the ramiform elements, an Sb with an antero-laterally directed process and in the possession of the characteristic ridge parallel to the basal margin.

Range: From 114 to 128 m in the Wandel Valley Formation of Børglum Elv and from 10 to 200 m in Kronprins Christian Land. From 848 to 1010 m in Cape Weber Formation on Ella Ø.

Number of Specimens: 24 Sa, 30 Sb, 30 Sc, 7 Sd, 44 M.

Pteracontiodus cryptodens (Mound, 1965a)

Pl. 14, Figs 1 - 4

1965a Eoneoprioniodus cryptodens, Mound, p. 177-8, text-Figs 1, 2, 12, 13.

1965b Acodus tripterolobus, Mound, p. 10, pl. 1, Figs 9-13.

1965b Acodus bialatus, Mound, p. 11, pl. 1, Figs 16-18, 24, text-Fig. 1C.

1971 Multioistodus cryptodens (Mound); Sweet, Ethington and Barnes, pl. 2, Figs 17A-C.

1971 Oistodus linguatus bilongatus Harris; Sweet, Ethington and Barnes, pl. 1, Fig. 23.

1977 Eoneoprioniodus bialatus (Mound); Barnes, p. 102, pl. 2, Figs 20-29.

1977 Eoneoprioniodus bilongatus (Harris); Barnes, p. 102, pl. 2, Figs 10-19.

1982 Pteracontiodus cryptodens (Mound); Ethington and Clark, p. 88-89, pl. 10, Figs 1-4, 6-10, (synonomy to 1977)

Remarks: Mound (1965a, b) described the elements of P. cryptodens as six form species, one of which, Eoneoprioniodus cryptodens, was the type species of a new genus. Subsequently these elements were assigned to Multioistodus Cullison (Sweet et al., 1971) and later returned to Eoneoprioniodus by Barnes (1977) who thought the genus was an ancestor of Multioistodus.

Ethington and Clark (1982) considered that E. cryptodens had a similar apparatus to the type species of Pteracontiodus, P. aquilatus Harris and Harris. Since the publication by Harris and Harris (1965) has 10 months priority over Mound (1965a), Mound's species was reassigned to Pteracontiodus.

The small number of specimens from the Narwhale Sound Formation conform well with the detailed description given by Ethington and Clark (1982).

Range: From 1260 to 1345 m in section PF 770824-1 on Ella Ø.

Number of Specimens: 1 Sa, 1 Sb, 1 Sc, 2 Sd.

Pteracontiodus? sp. A.

Pl. 14, Figs 5 - 8

Remarks: The posterior process is long and bears a blade-like keel. There is a long anticusp. Two of the three specimens bear a lateral costa which is sharp, narrow, decreases in height distally and does not project beyond the basal margin. The third specimen has two antero-lateral costae of similar morphology and that are asymmetrically disposed with respect to the plane of the element. The basal cavity is moderately deep with the apex situated well anterior. All elements are hyaline.

The elements with a single lateral costa are similar to the P element of *P. cryptodens* but the bicostate element does not closely resemble any in that apparatus.

Range: Found 260 m above the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 3

Genus PYGODUS Lamont and Lindström, 1957

1957 Pygodus Lamont and Lindström, p. 67

1962 Haddingodus Sweet and Bergström, p. 1229

Type Species: Pygodus anserinus Lamont and Lindström, 1957

Pygodus anserinus Lamont and Lindström, 1957

Pl. 14, Fig. 9

* 1957 Pygodus anserinus, Lamont and Lindstrom, p. 67-9, pl. 5, Figs 12, 13, text-Figs 1a-d.

1971 Pygodus anserinus Lamont and Lindström; Bergström, p. 147, pl. 2, Figs 20, 21, (synonomy to 1969)

1974 Pygodus anserinus Lamont and Lindström; Bergström, Riva and Kay, pl. 1, Figs 16, 17.

1978 Pygodus anserinus Lamont and Lindström; Bergström, pl. 79, Figs 1, 2.

1979 Pygodus anserinus Lamont and Lindström; Harris *et al.*, pl. 4, Fig. 17.

1980 Pygodus anserinus Lamont and Lindström; Simes, text-Figs 2, 3

1981 Pygodus anserinus Lamont and Lindström; Wang and Wang, pl. 1, Fig. 19.

1983 Pygodus anserinus Lamont and Lindstrom; Ni *in* Zeng *et al.*, pl. 12, Figs 4, 22.

Remarks: A single specimen of a pygodiform element was recovered from near the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak. The fourth denticle row is weakly developed and, although a juvenile, most closely resembles that figured by Harris *et al.* (1979)

Range: Found 90 m below the top of the Heim Bjerge Formation on C.H. Osterfeld Nunatak.

Number of Specimens: 1

Pygodus sp.

Pl. 14, Fig. 10

Remarks: A single haddingodiform specimen was recovered from the top of the Heim Bjerge Formation on Albert Heim Bjerge. As noted by Bergström (1971), it is difficult to distinguish between *P. anserinus* and *P. serrus* on the basis of the haddingodiform element.

Range: Found at 690 m in section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 1

Genus *REUTTERODUS* Serpagli, 1974

1974 *Reutterodus* Serpagli, p. 79

Type Species: *Reutterodus andinus* Serpagli, 1974

?*Reutterodus andinus* Serpagli, 1974

Pl. 14, Figs 11, 12

?* 1974 *Reutterodus andinus*, Serpagli, p. 79-81, pl. 17, Figs 4a-9d, pl. 28, Figs 1a-9d, text-Fig. 19, 20

? 1979 *Reutterodus depressus*, An, pl. 1, Fig. 14.

1982 ?*Reutterodus andinus* Serpagli; Ethington and Clark, p. 91, pl. 10, Fig. 18

1982 *Reutterodus andinus?* Serpagli; Repetski, p. 41, pl. 18, Figs 7a-c, pl. 19, Figs 1a-3c

1982 *Reutterodus? depressus* An; Ni *in* Zeng *et al.*, pl. 11, Fig. 27

Remarks: Serpagli (1974) described a trimembrate apparatus comprising a coniform element, a digyrate element with denticulate lateral processes and an alate element with denticulate lateral processes. These elements were said to form a continuous symmetry transition series and the digyrate ("unibranched") element was selected as the holotype.

Ethington and Clark (1982) subsequently recovered only the coniform element in quite large collections from the Pogonip Group and suggested that this element was not part of the *Reutterodus* apparatus.

The digyrate element was recovered by Repetski (1982) but only in small numbers and the assignment to Reutterodus andinus was again queried.

An (1979) figured and named a closely similar coniform element, Reutterodus? depressus. It differs from the coniform element of R. andinus in having a rather longer lateral process and more prominent inturned anterior margin. It may well, however, prove to be conspecific with the coniform described here.

?R. andinus is a potentially useful zonal taxon and its first appearance was used by Ethington and Clark (1982) to mark the base of the penultimate biostratigraphical interval in their biostratigraphical scheme for the Ibexian and lower Whiterockian.

Range: From 992 to 1161 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 3

Genus SCALPELLODUS Dzik, 1976

1976 Scalpellodus Dzik, p. 421

Type Species: Protopanderodus latus van Wamel, 1974

Scalpellodus? narvhalensis sp. nov.

Pl. 14 Figs 13 - 21

? 1976 Acontiodus rectus Lindstrom; Lee, p. 161, pl. 1, Fig. 2.

? 1976 Drepanodus altipes Henningsmoen; Lee, p. 164, pl. 1, Fig. 2.

? 1982 ?"Scolopodus" aff. "S." filosus Ethington and Clark; Ethington and Clark, p. 100, pl. 11, Figs 23, 25, 29.

1982 Protopanderodus longibasis (Lindström); Repetski, p. 40, pl. 17, Figs 11, 12.

Derivation of Name: After Narvhal Sound, a fjord bounding one side of Ella Ø.

Diagnosis: A trimembrate apparatus comprising a squat recurved r element, a short-based proclined q element and a long-based proclined p element. The p and q intergrade in morphology and have better developed striae than the r element. All elements are albid.

Description:

p element

Since p and q elements intergrade, only the end members of the series are described. The p is a slender element; cusp ⅓ - ½ total length of element. Upper edge of base long, usually approximately ½ the total element length. Element sharply curved at cusp/base junction, then straight, proclined and evenly tapering.

Anterior margin rounded, curving evenly into lateral faces; terminated by postero-lateral shoulders which fade out towards basal margin. Posterior face narrow, flat and with central keel; keel low, sharply rounded.

Base unexpanded, antero-basal angle 90°, postero-basal angle 90° although antero-basal angle may be slightly more and postero-basal angle correspondingly less. Basal margin straight; basal outline ovate; basal cavity very deep with straight anterior margin parallel to anterior margin of cusp, posterior margin straight, slopes anteriorly so that apex is close to the anterior margin and just before point of maximum recurvature.

Base and cusp finely striate but striae do not reach basal margin, leaving a smooth basal band.

<u>q element</u>

Base ⅓ total length of element; upper edge of base straight, curves round sharply into proclined cusp. Cusp straight or very slightly curved, antero-posteriorly compressed and may be asymmetrical with respect to base. Anterior margin rounded, curves evenly as far as postero-lateral costae. Posterior face convex.

Base moderately expanded posteriorly, antero-basal angle 90°, postero-basal angle 60°. Basal outline ovate; basal margin straight; basal cavity more shallow than that of p element, anterior margin parallel to anterior margin of base, posterior margin parallel to upper edge of base, apex near anterior margin just before point of maximum recurvature.

The transition from p to q is most easily seen in the change of cusp cross-section and the length of the base. From p to q the element becomes more antero-posteriorly compressed, the posterior keel is lost and the postero-lateral costae become more pronounced. The cusp becomes more recurved, and the maximum point of recurvature is situated progressively lower down the element. As a result the basal cavity becomes more shallow. The base becomes more expanded posteriorly and as a consequence the postero-basal angle decreases from 90° to about 60°.

<u>r element</u>

Upper edge of base about ½ the total element length, straight, very strongly recurved into cusp. Anterior margin straight in basal part then curves round rapidly through 90° or more into cusp. Cusp very short, straight, tapers rapidly, laterally compressed in cross-section, sharply rounded anteriorly and posteriorly, may be twisted with respect to base.

Base laterally compressed, antero-basal angle 70°, postero-basal angle 30 - 45°. Anterior margin of base sharply rounded, upper edge of base rounded; inner lateral face, to which the cusp is deflected, is flat, may bear a very low, rounded, antero-lateral costa which may have oblique striae. Basal outline roughly ovate but widest posteriorly; basal cavity shallow with anterior margin parallel to anterior margin of cusp but slightly convex (towards the cavity), posterior margin parallel to upper edge of base and straight, apex near anterior margin.

Surface frosting on many specimens prevents observation of the microsculpture. The few good specimens suggest that striae are not as well developed as on the p and q elements; striae of lower relief and wider spacing are seen on the inner lateral faces but the outer face is smooth. Other specimens may be entirely smooth. The smooth basal band is again present on striate specimens.

Remarks: The apparatus of Scalpellodus? narvhalensis with its short and long-based elements showing full transition and the squat recurved element is assignable to the Type IIIA category of Barnes et al. (1979). The apparatus thus consists of a long-based p, a short-based q and a squat, recurved r element.

Scalpellodus was erected by Dzik (1976) but emended by Löfgren (1978) who described its species in great detail. She interpreted the apparatus as consisting of three elements, a short-based drepanodiform, a long-based drepanodiform and a scandodiform. In S. gracilis at least, transitional specimens were found between short and long-based drepanodiforms (Löfgren, 1978, pl. 5, Figs 3a and b). The third element, the scandodiform, has a laterally compressed, strongly twisted cusp and an inwardly flaring base. All elements are striate with a smooth basal band.

Cooper (1981) ratified the apparatus structure in his description of a conodont fauna from the Horn Valley Siltstone and considered the short and long-based drepanodiforms of Löfgren (1978) to be Sc and Sa elements respectively. He classified the scandodiform as a transitional Sb.

The p and q elements of S? narvhalensis are very similar to the short and long-based drepanodiforms, showing similar development of short and long bases, striae and white matter. They differ only in the possession of postero-lateral shoulders or costae and seem to have less development of the symmetrical and asymmetrical forms mentioned by Löfgren (1978) although this may be a function of the small collections.

The principal difference between S? narvhalensis and other species of Scalpellodus, and the reason for the questioned generic assignment, is the profound difference between the r element of S? narvhalensis and the "scandodiform" of other species of Scalpellodus. In the r element, the cusp is much reduced in size, the base is enlarged, particularly posteriorly, and there may be a reduction in the development of striae. One of the few similarities is the asymmetrical development of the base with a greater expansion of the outer face and a flat inner face.

The genera most closely related to Scalpellodus are Cornuodus Fåhraeus and Protopanderodus Lindström. Löfgren (1978) considered that Cornuodus could be distinguished on the basis of microsculpture alone if necessary, with Scalpellodus being conspicuously striate.

Elements belonging to _Protopanderodus_ are distinctly costate and poorly striate. On these characters, _S? narvhalensis_ cannot be placed in either _Cornuodus_ or _Protopanderodus_.

An apparatus similar to that of _S? narvhalensis_ was figured by Ethington and Clark (1982) who described it as _"Scolopodus"_ aff. _"S." filosus_, although they admitted that the similarity to _"S." filosus_ might be superficial. The apparatus contains short and long based elements together with a squat element. All elements are conspicuously striate. The p and q elements differ from _S? narvhalensis_ in having circular cross-sections unmodified by posterior and postero-lateral costae. The r element differs in being fully striate.

Repetski (1982) also figured comparable elements as _Protopanderodus longibasis_ (Lindström). The r element is similar to that in _S? narvhalensis_ but the apparatus again appears to have a p element of unmodified circular to ovate cross-section. These specimens may be conspecific with _S? narvhalensis_ and if not are certainly very closely related.

Elements recorded here as _Scalpellodus?_ sp. A. may belong in the apparatus of _S? narvhalensis_. Their morphology could be an extreme variation of the p element but insufficient material is available to test this possibility.

Range: From 348 to 992 m in the Cape Weber Formation on Ella Ø and from 195 to 200 m up the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 62 p/q, 26 r.

Scalpellodus? sp. A.

Pl. 14, Figs 22, 23

Description: Base extremely long, slender, upper edge of base straight, curving rapidly into erect cusp. Cusp ⅓ length of element and often strongly twisted. Upper edge of base and posterior margin bear keel of moderate relief. Anterior margin rounded, curves evenly round to postero-lateral costae; costae rounded to sharp and may be asymmetrical. Antero-basal and postero-basal angles 90°. Basal margin straight; basal outline circular; basal cavity extremely deep, acutely conical, margins parallel to upper edge of base and anterior margin of base, apex near to anterior margin. Posterior keel fades out on base but costae persist until near basal margin. Element not striate; cusp albid.

Remarks: The element may be an extreme variant of the p element of S? narvhalensis. The lack of striations on the cusp and reduced amount of white matter are not consistent with this, however, and larger collections are needed to ascertain the relationship.

Range: From 868 to 880 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 8

Genus SCANDODUS Lindström, 1955

1955 Scandodus Lindström, p. 592

Type Species: Scandodus furnishi Lindström, 1955

Remarks: The apparatus of the type species is trimembrate, comprising a geniculate coniform element, a nongeniculate coniform element with suberect cusp and a short base and a recurved coniform element with a longer base. The elements are hyaline and form a transition series (Bergström, 1981). The relationship of Scandodus to other, similar, genera is discussed under Pteracontiodus - Remarks.

Scandodus furnishi Lindstrom sensu Ethington and Clark, 1964

Pl. 14, Figs 24, 25

1938 Oistodus inclinatus Branson and Mehl; Furnish, p. 330, pl. 41, Fig. 18.

1944 Oistodus sp.; Mehl and Ryan in Branson, pl. 7, Figs 5, 6

1964 Oistodus sp. aff. O. forceps Lindström; Ethington and Clark, p. 694, pl. 113, Fig. 19, pl. 114, Fig. 9.

1964 Scandodus furnishi Lindström; Ethington and Clark, p. 195, pl. 1, Fig. 11.

? 1965 Oistodus sp. A.; Ethington and Clark, p. 196, pl. 2, Fig. 18.

1970 Oistodus inaequalis Pander; Barnes and Tuke, p. 89, pl. 20, Figs 2, 3, 7.

p 1980 Oistodus sp. aff. O. inaequalis Pander; Grether and Clark, pl. 1, Fig. 14 only.

? 1982 Paltodus jemtlandicus Löfgren; Ethington and Clark, p. 75, pl. 8, Fig. 10, text-fig. 19.

1982 Oistodus inaequalis Pander; Stouge, pl. 4, Fig. 16.

1983 Oistodus inaequalis Pander; Stouge, pl. 2, Fig. 2.

Description: Geniculate, reclined at up to 45°. Upper edge of base short, sharp, angular junction with posterior margin of cusp. Posterior margin sharp, straight. Anterior margin sharp to keeled, straight; keel may be deflected inwards. Outer face flat, gently rounded anteriorly; inner face more convex, sometimes with low carina.

Basal outline asymmetrical, anterior pinched, widest at posterior, outer side flat to slightly convex, inner side highly convex. Outer face of base continuous with cusp or slightly expanded. Inner face highly expanded, sharp angular junction with cusp, greatest expansion at base of carina. Cavity opens inwards; apex shallow, below carina.

Cusp entirely albid or an inverted v of white matter leads from growth axis; some specimens just have a very thick growth axis.

Remarks: The elements described here differ from the element selected as the holotype of S. furnishi by Lindström (1955) in having a shorter cusp and a more triangular outline. S. furnishi has a trimembrate apparatus (Bergström, 1981) but the Midcontinent elements do not appear to occur in such an apparatus.

Specimens described as S. furnishi and Oistodus sp. aff. O. forceps Lindström by Ethington and Clark (1964) were considered to be conspecific with specimens included in Oistodus inaequalis by Ethington and Clark (1982). However, the specimen figured by them is closely similar to the r element of "Scandodus" sp. nov. A. and is included in that species. S. furnishi and O. sp. aff. O. forceps differ from the above r element in several ways: the profile is more triangular due to the shorter cusp, the carina is less well-developed, the antero-basal angle is larger and the basal cavity opens more noticeably inwards. In addition, white matter is of more variable, and usually lesser, development, whereas "S." sp. nov. A. is entirely albid. Further work may show that a relationship does exist between these elements, and morphological extremes do overlap somewhat, but I consider it preferable to retain them as separate taxa pending more conclusive evidence. To prevent the further confusion which would result by applying another name to the element, it is here included under S. furnishi sensu Ethington and Clark, the most complete description to date.

Range: S. furnishi occurs in the lower 30 m of the Wandel Valley Formation in central Peary Land and from the base up to 200 m in Kronprins Christian Land. It ranges from 164 to 495 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 77

"Scandodus" sp. nov. A.

Pl. 15, Figs 1 - 8

1970 Distomodus kentuckyensis Branson and Branson, Lee, p. 317, pl. 7, Figs 11, 12.

? 1971 Acontiodus oneotensis Furnish; Druce and Jones, p. 56-57, pl. 12, Figs 5a-7c only, (non Figs 3a-4b)

? 1971 Oistodus inaequalis Pander; Druce and Jones, p. 76, pl. 12, Figs 10a-13b, text-fig. 25a.

? 1974 Acodus deltatus Lindström; Viira, p. 41, pl. 2, Fig. 28, text-fig. 16a-c.

1978 Triangulodus sp. B.; Tipnis, Chatterton and Ludvigsen, pl. 3, Figs 18-20.

? 1980 New Genus C; Kennedy, pl. 2, Fig. 39.

1982 Oistodus inaequalis Pander; Ethington and Clark, p. 67-68, pl. 7, Fig. 7, text-fig. 15.

1982 "Scandodus" sp. 1; Ethington and Clark, p. 96-97, pl. 11, Figs 6, 7, text-fig. 22.

? 1982 Acodus? sp. cf. A. delicatus Branson and Mehl; Stouge, pl. 4, Figs 1, 2, 5.

? 1983 Acodus? sp. cf. A. delicatus Branson and Mehl; Stouge, pl. 3, Fig. 15.

1983 Scandodus cf. robustus Serpagli; Ni in Zeng et al., pl. 11, Fig. 15.

? 1983 Triangulodus bravibasis (Sergeeva)(sic); Ni in Zeng et al. pl. 11, Fig. 47.

Diagnosis: The apparatus is trimembrate. The p element has an anterior keel and a large rounded anticusp; the basal cavity is strongly expanded on the inner face only. The q element has an unexpanded base and an anterior keel deflected inwards. The r element has a characteristically extended antero-basal corner and a basal cavity strongly expanded only on the inner face.

Description:

p element

Cusp erect. Upper edge of base short, straight, sharp-edged, meeting posterior margin of cusp at angle of 90^{o} or rather less. Posterior margin keeled, straight. Anterior margin keeled; keel higher than on posterior margin, deflected inwards, narrowing distally, proximally produces as large, rounded anticusp which may be deflected outwards. Outer face flat or gently rounded. Inner face with carina ½ in from anterior margin.

Basal margin straight or distinctly angular, angle just to posterior of anticusp. Basal outline equilaterally triangular with one corner on inner face. Outer face unexpanded, inner side strongly expanded, some specimens with costa along maximum curvature of inner face.

Basal cavity shallow, asymmetrically triangular in profile, anterior margin in line with posterior margin of anticusp, posterior margin parallel to upper edge of base.

q element

Cusp reclined. Upper edge of base very short, with a low keel; junction with posterior margin angular or sharply curved. Posterior margin sharp to keeled, gently curved. Anterior margin keeled, deflected inwards; short angular anticusp may be developed. Outer face flat to gently rounded. Inner face rounded, keel deflection may create groove just posterior to keel.

Basal margin straight. Basal outline biconvex, pinched anteriorly. Outer face of basal cavity unexpanded, inner face gently expanded. Basal cavity relatively deep, anterior parallel to anterior margin, posterior parallel to upper edge of base, apex anterior.

r element

Geniculate. Upper edge of base extremely short, keeled. Posterior margin straight, keeled. Anterior margin keeled, straight or slightly curved, may be deflected inwards. Outer face gently rounded, inner face carinate.

Antero-basal corner extended, basal margin straight. Base unexpanded on outer face, greatly expanded on posterior part of inner face as continuation of carina, extended as narrow slit to antero-basal corner.

Intermediate specimens between p and q and r elements are common. All specimens are albid above the basal region.

Remarks: The p elements of "Scandodus" sp. nov. A. have been figured by Tipnis et al. (1978) and Ethington and Clark (1982, pl. 11, Figs 6, 7). The element figured as O. inaequalis by Ethington and Clark (1982, pl. 7, Fig. 7) is morphologically close to the r element of "S." sp. nov. A but has a much longer range than "S." sp. 1, the p element.

Oistodus sp. 6 of Ethington and Clark (1982), from the House Limestone, resembles the r element but is substantially older than the Greenland specimens. As suggested by Ethington and Clark (1982), the specimens may be conspecific with O. inaequalis of Druce and Jones (1971) and together with Acontiodus oneotensis of the latter authors may constitute the apparatus of an older, but related, species.

Triangulodus cf. T. brevibasis (Sergeeva) of Repetski (1982) contains some very similar elements to those in "S." sp. nov. A. The erect scnadodiform, acodiform and drepanodiform elements compare closely with the p and q elements. The r element (oistodiform of Repetski) is, however, very different and, in addition, elements corresponding to his trichonodelliform and distacodiform elements were not found in Greenland.

The r element is morphologically similar to "Paltodus"? sweeti Serpagli and "Scandodus" robustus Serpagli described from the San Juan Formation by Serpagli (1974). These elements together with "Oistodus" hunickeni Serpagli and "Scandodus" americanus Serpagli were interpreted by Ethington and Clark (1982) as belonging to two distinct apparatus. The older apparatus comprises the form species "P."? sweeti and _"S." americanus_ and the younger contains acostate and laterally costate elements of _"S." robustus_, possibly with _"O." hunickeni_. These two species differ in detail from _"S."_ sp. nov. A. but probably belong to the same genus, although adequate material is not available to fully assess the relationship.

The generic affinity of _"S."_ sp. nov. A. is conjectural. The elements are morphologically similar to those placed in _Diaphorodus_ but the apparatus lacks a ramiform transition series, nor can the species be assigned to _Scandodus_ since the elements are albid. _Trigonodus_ Nieper, as reconstructed by Cooper (1981), is also ruled out because its species are hyaline. The apparatus of _Tripodus_ Bradshaw is albid but quinquimembrate and the elements have basally-produced costae (Ethington and Clark, 1982).

This apparatus, and those containing _"P." sweeti_ and _"S." robustus_, should probably be assigned to a new genus. Until adequate material is available, I prefer to follow the example of Serpagli (1974) and Ethington and Clark (1982) and assign this species to _"Scandodus"_.

Range: _"Scandodus"_ sp. nov. A. occurs in the lower 128 m of the Wandel Valley Formation in central Peary Land and the lower 200 m in Kronprins Christian Land. On Ella Ø the species has a range from 164 to 1010 m.

Number of Specimens: 134 p elements, 174 q elements, 125 r elements.

Scandodiform 1

Pl.15, Fig. 9

Description: Upper edge of base keeled, short, angular junction with posterior margin. Cusp reclined, anterior margin keeled and gently curved, posterior margin keeled and gently curved; outer face gently convex, inner face convex and with low median carina. Posterior margin serrate in large specimens.

Basal outline lenticular; basal margin straight to convex. Basal cavity shallow outer face gently convex, inner face strongly expanded. Element hyaline.

Remarks: This element was recovered from a single sample in the Wandel Valley Formation. It is most similar to the M element of Multioistodus? but lacks the posterior denticle. M? compressus with normally denticulate M elements does occur in the same sample.

Range: Found at 168 m above the base of the Wandel Valley Formation in central Peary Land.

Number of Specimens: 11

Genus SCOLOPODUS Pander, 1856

1865 Scolopodus Pander, p. 25

Type Species: Scolopodus sublaevis Pander, 1856

Remarks: The apparatus of Scolopodus was first reconstructed by Lindström (1971) who, in the absence of information regarding Pander's type species, provisionally based the description of the genus on S. rex Lindström. The apparatus was diagnosed as including costate, hyaline coniform elements of rounded, symmetrical and asymmetrical cross-section.

Utilising material from Öland, Fåhraeus (1982) was able to assemble Pander's (1856) form species into two apparatuses: S. sublaevis, the type species, and S. quadratus. Fåhraeus considered S. rex Lindström to be a junior synonym of S. quadratus and he amended the diagnosis of Scolopodus to include apparatus of hyaline, slender, costate coniform elements with a transition series of symmetrical to asymmetrical cusp cross-section.

In the past, it has been traditional to assign many Midcontinent Province coniform elements to Scolopodus simply on the basis of their costate morphology and regardless of white matter or basal cavity characteristics. As the apparatuses of these elements are becoming known, many are being assigned to other genera; for example, Glyptoconus quadraplicatus, Oneotodus costatus and Tropodus comptus (Kennedy, 1980; Ethington and Brand, 1981) previously had some or all of their elements assigned to _Scolopodus_. A few species described herein are still from apparatuses of uncertain structure and, consequently, uncertain generic affinity. These species are retained for the time being in _"Scolopodus"_.

"Scolopodus" emarginatus Barnes and Tuke, 1970

Pl. 15, Fig. 10

1944 _Paltodus_ n. sp.; Mehl and Ryan _in_ Branson, p. 52, pl. 7,

* 1970 _Scolopodus emarginatus_, Barnes and Tuke, p. 91-92, pl. 18, Figs 2, 6-8, text-Fig. 6C.

? 1982 _"Scolopodus" emarginatus_ Barnes and Tuke; Ethington and Clark, p. 99-100, pl. 11, Figs 15, 16.

1982 _Scolopodus emarginatus_ Barnes and Tuke; Repetski, p. 47, pl. 22, Fig. 3.

1982 _Scolopodus emarginatus_ Barnes and Tuke; Stouge, pl. 5, Figs 8, 9.

Remarks: The specimens at hand conform closely to the detailed description by Barnes and Tuke (1970) who noted that their specimens of _"S." emarginatus_ were smooth. Ethington and Clark (1982) widened the diagnosis to include specimens which had low, widely-spaced costae on the lateral faces. The Greenland material is, on the whole, smooth although some specimens are faintly striate and a few have coarse striae around the basal margin that rapidly fade out. The specimens of Ethington and Clark (1982) may represent a closely related but distinct species and are here included in synonomy with some reservation.

Barnes and Tuke (1970) commented that some of their specimens were mildly asymmetrical. Those from Greenland are commonly asymmetrical and some specimens from the Cape Weber Formation, have one lateral face which is consequently much reduced in size.

Range: "S." emarginatus occurs up to 147 m in the Wandel Valley Formation of central Peary Land and up to 260 m in Kronprins Christian Land. It ranges from 178 to 1390 m in section PF 770824-1 on Ella Ø.

Number of Specimens: 56

"Scolopodus" filosus Ethington and Clark, 1964

Pl. 15, Fig. 11

*	1964	Scolopodus filosus, Ethington and Clark, p. 699, pl. 114, Figs 12, 17, 18, 9, text-Fig. 2E.
non	1975	Scolopodus cf. S. filosus Ethington and Clark; Cooper and Druce, p. 576, Fig. 32.
	1982	Scolopodus filosus Ethington and Clark; Ethington and and Clark, p. 100, pl. 11, Fig. 22, (synonomy to 1978).
	1982	Scolopodus filosus Ethington and Clark; Repetski, p. 47, pl. 22, Fig. 2a-c.
non	1982	Scolopodus filosus xyron, Repetski, p. 47, pl. 22, Figs 1a-6c, text-Fig. 7M.
?	1982	Semiacontiodus sp.cf. S. cordis (Hamar); Stouge, pl. 5, Figs 12, 13.

? 1983 Semiacontiodus sp. cf. S. cordis (Hamar); Stouge, pl. 4, Fig. 11.

Remarks: S. filosus was thoroughly described by Ethington and Clark (1964) and the Greenland material conforms well with their description. Ethington and Clark (1982) thought it possible that elements of this morphology may be rare variants of the "S." gracilis apparatus, in which elements lack the characteristic posterior groove. The morphologies of the two taxa are certainly very similar and the samples in the Wandel Valley Formation which contain extremely large numbers of "S." gracilis elements also have the greatest recorded abundances of "S." filosus. I consider it very likely that "S." filosus is conspecific with "S." gracilis, but decline to formalise this pending further confirmation.

A subspecies of "S." filosus, S. filosus xyron was erected by Repetski (1982). The two taxa are here considered to be distinct species and Repetski's species is reassigned to Eucharodus (q.v.).

Range: "S." filosus occurs from the base of the Wandel Valley Formation to a height of 200 m in Kronprins Christian Land and at 384 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 42

"Scolopodus" gracilis Ethington and Clark, 1964

Pl. 15, Figs. 12 - 17

1941 Drepanodus striatus, Graves and Ellison, p. 11, pl. 1, Figs 3, 12.

* 1964 Scolopodus gracilis, Ethington and Clark, p. 699, pl. 115, Figs 2-4, 8, 9.

1964 Scolopodus triangularis, Ethington and Clark, p. 700, pl. 115, Figs 6, 11, 13, 17, text-Fig. 21.

1965 Scolopodus striolatus, Harris and Harris, p. 38-39, pl. 1, Figs 6a-c.

1971 Paltodus sp. A; Sweet, Ethington and Barnes, p. 168, pl. 1, Fig. 14.

1973 Protopanderodus asymmetricus, Barnes and Poplawski, p. 781-782, pl. 1, Figs 12, 12a, 14, 16, text-Fig. 2A.

1973 Scolopodus gracilis Ethington and Clark, Barnes and Poplawski, p. 786-7, pl. 3, Figs 6-8a, text-Fig. 2 G,H.

1979 Juanognathus asymmetricus (Barnes and Poplawski); Bergström, p. 303, Fig. 4E.

1980 Scolopodus triangularis Ethington and Clark; Grether and Clark, pl. 1, Fig. 41.

1980 "Scolopodus" gracilis Ethington and Clark; Mayr, Uyeno, Tipnis and Barnes, p. 211, pl. 32.1, Fig. 2.

1981 Scolopodus gracilis Ethington and Clark; Repetski and Perry, pl. 2, Figs 1,2.

1981 Scolopodus gracilis Ethington and Clark; An, pl. 3, Fig. 6.

1982 Scolopodus paracornuformis, Ethington and Clark, p. 102, pl. 11, Fig. 21, text-Fig. 25.

1982 Protopanderodus asymmetricus Barnes and Poplawski; Repetski, p. 37, pl. 15, Fig. 1.

1982 Scolopodus gracilis Ethington and Clark; Repetski, p. 48, pl. 22, Figs 5, 8-11.

1982 "Scolopodus" gracilis Ethington and Clark; Stouge, p. 43, pl. 2, Figs 12, 13, pl. 5, Figs 10, 11.

1982 Semiacontiodus asymmetricus; Stouge, pl. 5, Figs 14-16.

1983 Scolopodus? gracilis Ethington and Clark; Stouge, pl. 1, Fig. 2, pl. 3, Figs 8, 9.

1983 Semiacontiodus sp. cf. S. asymmetricus (Barnes and Poplawski); Stouge, pl. 4, Figs 3-7.

Remarks: Three clusters containing elements of "S." gracilis were recovered from the Cape Weber Formation on Albert Heim Bjerge and Ells Ø. The relative positions of elements within these clusters and their palaeobiological significance is discussed in Chapter 7 but the taxonomic implications are outlined here.

Two of the clusters only contain s elements, previously referred to the form species S. gracilis and S. triangularis. All three clusters support the inclusion of S. triangularis within the apparatus, as suggested by Barnes and Poplawski (1973). The v-shaped posterior margins abut the angular anterior margin of the adjacent element and up to four elements occur together in nested sets. The posterior margin of the posterior element in such clusters bears a narrow groove rather than a v-shaped groove.

A single cluster (Pl. 20, Figs 3,4) includes an element of the type previously assigned to Protopanderodus asymmetricus Barnes and Poplawski. The posterior face of this element is fused to the lateral faces of a nested set of s elements and has a single s element fused to the anterior face. There is little chance that the juxtaposition and fusion could be purely fortuitous in such an organised cluster. Elements referable to P. asymmetricus are thus included in the apparatus of "S." gracilis and are interpreted as t elements.

A third, u, element is included in the apparatus, although it is not present in the clusters. It displays closely similar morphology to the s and t elements and the three elements consistently co-occur in the same samples. They also show related abundance peaks and maintain a consistent ratio of approximately 6:1:1 (s:t:u). The u element is symmetrical, antero-posteriorly compressed and has two postero-lateral grooves. It has previously been considered as a symmetrical member of the same apparatus as P. asymmetricus (Nowlan, 1976; Stouge, 1982, 1983). The existence of an apparatus containing these two elements was also considered possible by Ethington and Clark, 1982). However, due to the lack of firm evidence, their collections being relatively small, they described the element as a new species, "Scolopodus" paracornuformis.

In summary, the apparatus of "S." gracilis is interpreted as trimembrate, consisting of a posteriorly grooved s element, a twisted, asymmetrical, antero-posteriorly compressed t element and a symmetrical, antero-posteriorly compressed u element. All elements are striate and most specimens are hyaline, although a very small number do develop cloudy white matter in the cusp.

This apparatus does not conform with that of the type species of Scolopodus (Fåhraeus, 1982) nor with any other Ordovician genus. The species must, eventually, be assigned to a new genus but several major taxonomic problems remain to be resolved. One of these is the discrepancy in the range of the form taxon S. gracilis with respect to that of the form taxa P. asymmetricus and S. paracornuformis. S. gracilis ranges from the G. quadraplicatus/ S. aff. S rex Interval to the H. sinuosa Interval in the Ibex area of Utah (Ethington and Clark, 1982) but the combined range of the other two is restricted to the J. gananda/R? andinus Interval to the M. flabellum/T. laevis Interval. The s element thus has a range which apparently extends both below and above that of the t and u elements. This pattern is repeated in other areas of the Midcontinent Province (Repetski, 1982; Nowlan, 1976) and can be attributed to three possible causes:

i) Firstly, it may be due to small collections giving an artificially longer range to the more abundant element. The early descriptions were of small collections and the t and u elements may not have been recovered, particularly in the Whiterockian where yields are very low. This could also explain the paucity of citations of the t and u elements. Faunas of this age have, however, become much better documented of late (Ethington and Clark, 1982; Repetski, 1982) and the discrepancy in ranges remains.

ii) A second explanation is that the earliest apparatus was unimembrate, consisting solely of S. gracilis-like s elements, and the elements subsequently become differentiated to give the trimembrate apparatus described above. The extension of the range of S. gracilis morphotypes above the other elements remain to be explained but could still be due to very low yields in the lower Whiterockian.

iii) The final possibility is that two apparatuses coexisted in the upper Ibexian, one unimembrate, with a long range, and one trimembrate, but both with elements of S. gracilis morphology. This latter model is, however, particularly difficult to test.

If the range discrepancy is solved, the problem remains as to which of the available names should be applied to the apparatus; D. striatus Graves and Ellison, S. gracilis Ethington and Clark, S. striolatus Harris and Harris, P. asymmetricus Barnes and Poplawski or S. paracornuformis Ethington and Clark. The apparatus is currently described under Scolopodus gracilis Ethington and Clark since the senior available name, Drepanodus striatus Graves and Ellison, is a junior homonym of Scolopodus striatus Pander. Should the species be placed in a different genus the senior synonym will be

Drepanodus striatus and Scolopodus gracilis will become a junior objective synonym (ICZN article 59c). If the existence of two apparatuses containing S. gracilis-like elements is proven, it will have to be decided which of the three available names for s elements, all senior to P. asymmetricus, are applicable to which apparatus. Until such problems are resolved it is considered preferable to retain this species under "S." gracilis, although the need for assignment to a different genus is recognised.

Range: "S." gracilis occurs from the base of the Wandel Valley Formation to 260 m in Kronprins Christian Land and 71 - 214 m above the base in Børglum Elv. It occurs from 150 to 1390 m above the base of section PF 770824-1 on Ella Ø.

Number of Specimens: 1447 s, 229 t, 232 u.

Scolopodus quadratus Pander, 1856?

Pl. 15, Fig. 18

?* 1856 Scolopodus quadratus, Pander, p. 26, pl. 2, Figs 6a-d, pl. A, Fig. 5d.

? 1856 Scolopodus costatus, Pander, p. 26, pl. 2, Figs 7a-d, Pl. A, Fig. 5e.

? 1856 Scolopodus striatus, Pander, p. 26, pl. 2, Figs 8a-d, pl. A, Fig. 5f.

? 1955 Scolopodus rex, Lindström, P. 595-6, pl. 3, Fig. 32.

? 1955 Scolopodus rex paltodiformis, Lindstrom, p. 596, pl. 3, Figs 33, 34.

1982 aff. Scolopodus rex Lindström, Ethington and Clark, p. 104-5, pl. 12, Figs 1, 2 (synonomy to 1978)

? 1982 Scolopodus quadratus Pander; Fåhraeus, p. 21-22, pl. 2, Figs 1-8, 15.

1982 Scolopodus rex Lindström; Repetski, p. 50-1, pl. 23, Fig. 6.

1982 Scolopodus rex paltodiformis Lindström; Repetski, p. 51, pl. 23, Figs 8, 10, 11, pl. 24, Fig. 2, text-Fig. 7N.

1982 Scolopodus cf. S. rex Lindström; Stouge, pl. 6, Figs 12, 13.

Remarks: Fåhraeus (1982) included S. rex Lindström as a junior synonym of S. quadratus Pander. Ethington and Clark (1982) and Repetski (1982) have given thorough descriptions of possible representatives of S. quadratus from the Midcontinent Province. The Greenland material is comparable, but is too sparse to assess whether it is truly conspecific with S. quadratus.

Range: From 20 to 115 m in the Wandel Valley Formation in Kronprins Christian Land and from 976 to 992 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 9

Scolopodus sp. A.

Pl. 15, Fig. 19

Remarks: Laterally compressed and anteriorly costate. The proximal half of the posterior margin has a high keel. The base is unexpanded; the basal cavity is shallow, opens anteriorly and posteriorly and the apex is anterior. Cusp albid above base.

Range: Found 164 m above the base of the Cape Weber Formation on Ella Ø.

Number of Specimens: 1

Genus SEMIACONTIODUS Miller, 1969

1969 Semiacontiodus Miller, p. 420

Type Species: Acontiodus (Semiacontiodus) nogamii Miller, 1969.

Semiacontiodus sp. A.

Pl. 15, Fig. 20

? 1971 Acoodina navicula, Abaimova, p. 76, pl. 10, Fig. 4.

? 1971 Scolopodus staufferi (Furnish); Jones, p. 67, pl. 6, Figs 7a-c.

? 1975 Acodina navicula Abaimova, p. 36-37, pl. 1, Figs 15a-16b, text-Fig. 6.5, 6.6.

1981 Juanognathus? sp. A.; Landing and Barnes, p. 1616, 1618, pl. 3, Figs 13, 16, pl. 4, Figs 1-6, 8, 10, text-Fig. 30, 32, 33, 35, 36, 39.

Remarks: The specimens from Ella Ø are albid, the anterior margin is rounded, the lateral faces meeting these at an acute angle. The postero-lateral costae are sharp to sharply rounded and the posterior face enclosed by them is deep and v-shaped. On large specimens the lateral faces may bear longitudinal, rounded ridges and grooves of low relief.

Landing and Barnes (1981) thought these elements might belong in an undescribed apparatus of Juanognathus but the range of morphologies seen in apparatuses of Juanognathus is not evident in the small collections from Devon Island (Landing and Barnes, 1981) or Ella Ø. The asymmetrical and symmetrical element-types reported by Landing and Barnes (1981) do, however, agree with the emended diagnosis of Semiacontiodus (Miller, 1980). The symmetrical element of Semiacontiodus is somewhat antero-posteriorly compressed and has postero-lateral costae, a description which Semiacontiodus sp. A. fits well.

Range: Semiacontiodus sp. A. occurs up to 46 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 7

Genus SIBIRIODUS Moskalenko, 1982

1982 Sibiriodus Moskalenko, p. 141

Type Species: Sibiriodus kulymbensis Moskalenko, 1982

Sibiriodus? kalalekus sp. nov.

Pl. 16, Figs 1 - 10

Derivation of Name: Kalalek (Greenlandic), Greenlander.

Diagnosis: A quadrimembrate apparatus of scandodiform, drepanodiform, acodiform and trichonodelliform elements. Transition from acodiform to trichonodelliform elements is smooth. Lateral costae of the trichonodelliform element are sharp and may be produced basally as short, adenticulate processes. Elements are hyaline with only a thin strand of white matter along the growth axis.

Description:

Scandodiform element

Cusp erect, short straight. Anterior margin very slightly curved proximally, produced as a short anticusp basally. Posterior margin sharp, straight distally, proximally keeled and curving gently into short upper edge of base. Outer face gently convex. Inner face concave but with weak carina medially. Inner face of basal cavity expanded as continuation of median carina. Outer face has acutely rounded expansion of the basal cavity which is more restricted than on inner face.

Basal margin concave, basal outline biconvex, pinched anteriorly and posteriorly. Basal cavity shallow, apex below carina.

Drepanodiform element

Cusp erect to proclined, long. Anterior margin sharp and deflected inwards; narrow, shallow groove posterior to inturned margin, may be produced as anticusp. Posterior margin sharp, curving evenly into short upper edge of base. Outer face strongly convex, inner face less convex.

Basal cavity unexpanded, basal margin straight; basal outline has straight inner face, curved outer face. Basal cavity shallow, apex anterior of midline.

Acodiform element

Cusp erect to proclined, long. Anterior face rounded. Posterior margin keeled curving evenly into long upper edge of base. Latter may project a short distance beyond basal margin. One face bears antero-lateral costa directed antero-laterally, opposite face bears a postero-lateral costa directed postero-laterally; costae sharp, produced basally as adenticulate processes. Lateral face between antero-lateral costa and posterior margin gently convex, between postero-lateral costa and posterior margin flat.

Basal outline sub-circular. Basal cavity moderately deep, apex anterior.

Trichonodelliform element

Cusp erect to proclined, anterior face rounded, posterior margin keeled and curving evenly into long upper edge of base. Lateral costae situated postero-laterally, sharp, produced basally as short adenticulate processes. Lateral faces flat.

Basal outline triangular. Basal cavity moderately deep, apex anterior.

All elements are hyaline with just a very thin strand of white matter along the growth axis.

Remarks: The adenticulate processes are commonly broken off the drepanodiform, acodiform and trichonodelliform elements, this may cause problems in identifying these elements. The element here termed acodiform does not fully conform with the conventional usage in that there are antero-lateral and postero-lateral costae with a keeled posterior margin rather than sharp anterior and posterior margins and one lateral costa. There is a smooth transition between this element and the trichonodelliform element.

The morphologies and transitions are similar to those of species of *Pteracontiodus* Harris and Harris and *Trigonodus* Nieper from which the apparatus differs in lacking an oistodiform. It differs from *Tripodus* Bradshaw, as reconstructed by Ethington and Clark (1982), in being hyaline and lacking the oistodiform and paltodiform elements.

Sibiriodus was first described from the Kulumbe River of Siberia by Moskalenko (1982) who included scandodiform, drepanodiform, acodiform and distacodiform elements. This apparatus is comparable to that of S? kalalekus but differs in that the acodiform has sharp anterior and posterior margins and a lateral costa and in possessing a distacodiform rather than trichonodelliform element. S. kulymbensis also lacks the basally produced costae on the acodiform and trichonodelliform elements and an anticusp on the scandodiform and drepanodiform elements.

Range: From 17 to 1.5 m below the top of the Wandel Valley Formation in western Peary Land and 70 to 3 m below the top in central Peary Land. From 426 to 690 m above the base of section PF 770713-1 on Albert Heim Bjerge and 90 to 40 m below the top of the Heim Bjerge Formation on C.H. Ostenfeld Nunatak.

Genus STEREOCONUS Branson and Mehl, 1933

1933 Stereoconus Branson and Mehl, p. 27

Type Species: Stereoconus gracilis Branson and Mehl, 1933

Stereoconus cf. S. circulus Moskalenko, 1970

Pl. 16, Fig. 11

?* 1970 Stereoconus circulus, Moskalenko, p. 49, pl. 4, Figs 1a-c, 2.

Remarks: The single specimen differs from the type in having a 90^{o} junction between the cusp and the base and a basal cavity which is extended further to the posterior.

Range: Found at 168 m above the base of section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 1

Genus TRIGONODUS Nieper, 1969

1969 Trigonodus Nieper, p. 02

1974 Triangulodus van Wamel, p. 96

Type Species: Oistodus larapintinensis Crespin, 1943

Remarks: Cooper (1981) revised the diagnosis of Trigonodus Nieper to include seximembrate apparatuses containing hyaline elements. The apparatus consists of a geniculate coniform, scandodontiform and a symmetry transition series with transition expressed by the number and position of lateral costae. Scandodus brevibasis (Sergeeva) as reconstructed by Lindström (1971) and Löfgren (1978) was transferred to Trigonodus by Cooper (1981) since its apparatus differs significantly from the type species of Scandodus, which is trimembrate. Van Wamel (1976) also recognised this difference and chose Oistodus brevibasis Sergeeva as the type species of Triangulodus van Wamel, which is thus a junior synonym of Trigonodus Nieper.

Trigonodus differs from Pteracontiodus Harris and Harris in its lack of adenticulate processes and from Tripodus Bradshaw, as revised by Ethington and Clark (1982), in its lack of processes and hyaline nature.

Trigonodus? sinuosus (Mound, 1965b)

Pl. 17, Figs 10 - 13

1965b Acodus campanula, Mound, p. 8-9, pl. 1, Figs 4-6.

1965b Acontiodus curvatus, Mound, p. 11-12, pl. 1, Figs 19-21, text-Fig. 1D.

1965b Distacodus symmetricus, Mound, p. 16, pl. 2, Figs 1-3, text-Fig. 1E.

?p 1965b Oistodus abundans Branson and Mehl; Mound, p. 26, pl. 3, Fig. 23 only.

1965b Scandodus sinuosus, Mound, p. 33-4, pl. 4, Figs 21, 22, 24, text-Fig. 1J.

1982 Scandodus sinuosus Mound; Ethington and Clark, p. 94-6, pl. 11, Figs 1-5, (synonomy to 1978).

1982 Scandodus sinuosus Mound; Rexroad, Droste and Ethington, p. 11, pl. 1, Fig 21, pl. 2, Fig. 14.

Remarks: T? sinuosus was thoroughly described by Ethington and Clark (1982) who commented on the similarity of the apparatus to T. brevibasis (Sergeeva). Although very similar in apparatus structure to T. brevibasis as reconstructed by van Wamel (1974), Triangulodus was rejected as an available genus by Ethington and Clark (1982) and the species was placed in Scandodus.

Ethington and Clark (1982) noted that geniculate elements of T? sinuosus (oistodiforms of Ethington and Clark) had an irregular distribution and McHargue (1974) excluded them from the apparatus. No geniculate elements were recovered from Greenland and only one distacodiform, but the collections are only small in comparison with those from Ibex (Ethington and Clark, 1982). Until it can be established whether there is a geniculate element in the apparatus of this species, the assignment to Trigonodus must remain tentative.

Range: From 100 to 28 m below the top of the Wandel Valley Formation in western Peary Land, from 168 to 239 m above the base in central Peary Land and 118 to 97 m below the top. The species was found in a single sample 30 m below the top of the Wandel Valley Formation in Kronprins Christian Land. It ranges from 85 to 258 m above the base of section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 48 scandodiform, 28 acodiform, 8 trichonodelliform, 1 distacodiform.

Genus TROPODUS Kennedy, 1980

1980 Tropodus Kennedy, p. 65

Type Species: Paltodus comptus Branson and Mehl, 1933

Remarks: The apparatus is quadrimembrate or quinquimembrate and consists of a fluid transition series of tricostate, quadricostate, symmetrical and asymmetrical quinquicostate (comptiform) elements. Barnes et al. (1979) considered Walliserodus to have a Type IB apparatus but Kennedy (1980) subsequently removed the Lower Ordovician species into Tropodus. The apparatus conforms most closely to Type IA but due to the fluid transition intermediate element types are seen, as in Juanognathus. Indeed, the similarities in the transition series, costal morphology and white matter distribution probably warrant inclusion of these two genera within the same family.

Within a Type IA apparatus the tricostate forms would be s_1 elements, the quadricostate forms s_2, the asymmetrical quinquicostate forms t and the symmetrical quinquicostate forms u elements.

Tropodus australis (Serpagli, 1974)

Pl. 16, Figs 12 - 14

* 1974 Walliserodus australis, Serpagli, p. 73-75, pl. 19, Figs 5-10, pl. 29, Figs 18-25, text-Figs 23, 24.

1976 Walliserodus australis Serpagli; Landing, p. 641-642, pl. 4, Figs 16, 19, 22, 23.

Remarks: The small collection of elements referred to this species was recovered from samples immediately above the highest occurrence of T. comptus (Branson and Mehl). The most distinctive element is the quinquicostate form which has very strong, basally projecting costae. The postero-lateral costae of this element may bear small, serrate denticles at the proximal end. Similar serrate elements have been figured by Serpagli (1974, pl. 19, Fig. 7, pl. 29, Fig. 15) and Landing (1976, pl. 4, Fig. 19) and one specimen of this type was found in the Cape Weber Formation.

The tricostate elements are usually asymmetrical in cusp cross-section and also have basally projecting costae. They outnumber the quinquicostate elements by 2:1 in the San Juan Limestone (Serpagli, 1974) and by 3:1 in the Cape Weber Formation.

The apparatus is completed by laterally compressed quadricostate elements, with anterior, posterior and asymmetrically disposed lateral costae, and comptiform elements. The comptiform elements figured by Serpagli (1976) included laterally expanded and compressed forms. The single specimen recovered from the Cape Weber Formation is of the latter type.

Range: 992 - 1010 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: Tricostate 6; laterally compressed quadricostate 2; quinquicostate 2; comptiform 1.

Tropodus comptus (Branson and Mehl, 1933)

Pl. 16, Figs 15 - 25

*	1933	Paltodus comptus, Branson and Mehl, p. 61, pl. 4, Fig. 9.
	1933	Scolopodus pseudoquadratus, Branson and Mehl, p. 63, pl. 4, Fig. 19.
?	1968	Acontiodus staufferi Furnish; Mound, pl. 1, Figs 40, 49 only.
non	1975	Scolopodus pseudoquadratus Branson and Mehl; Abaimova, p. 97-98, pl. 9, Figs 8-10, text-Fig. 8. 5, 7, 8-11.
?	1975	Scolopodus sexiplicatus Jones; Cooper and Druce, p.578-9, pl. 1, Fig. 29.
	1971	Paltodus sp. A.; Ethington and Clark, pl. 2, Fig. 12.
	1980	Tropodus comptus (Branson and Mehl); Kennedy, p. 65-66, pl. 2, Figs 20-27, (synonomy to 1978).
	1982	Walliserodus comptus (Branson and Mehl); Ethington and Clark, p. 114-116, pl. 13, Figs 6, 7, 11-13, text-Fig. 34.
	1982	Scolopodus pseudoquadratus (Branson and Mehl); Repetski, p. 50, pl. 23, Fig. 7.
	1982	Scolopodus aff. S. pseudoquadratus (Branson and Mehl); Repetski, p. 50, pl. 23, Fig. 9, text-Fig. 7Q.
	1982	Tropodus comptus (Branson and Mehl); Stouge, p. 45, pl. 4, Figs 3, 4, 6-8.
	1983	Tropodus comptus (Branson and Mehl); Stouge, pl. 3, Figs 13, 14.

Diagnosis: A quadrimembrate apparatus composed of tricostate quadricostate, symmetrical quinquicostate and comptiform elements. All elements have long bases and are albid. The costae are lower in relief than those on *T. australis* and are never denticulate.

Description:

Tricostate element

Upper edge of base straight, curves round evenly into posterior margin. Upper edge and posterior margin marked by costa; costa sharp, well-defined, offset from midline towards outer face. Inner lateral face convex, maximum point of curvature near posterior costa. Outer lateral face flat. Antero-lateral costae symmetrically disposed, deflected postero-laterally. Anterior face broadly rounded but depressed in the centre basally.

Quadricostate element

Upper edge of base straight, curving evenly into posterior margin of proclined cusp. Element bowed. Posterior margin marked by two sharp, well-defined costae; one posterior, the other postero-lateral, spacing varies and may become posterior and lateral in position. Outer lateral face flat, inner lateral face convex. Antero-lateral costae symmetrically disposed, deflected postero-laterally. Anterior face broadly rounded, depressed centrally at antero-basal corner.

Symmetrical quinquicostate element

Upper edge of base straight, curves evenly into posterior margin of proclined cusp. Element not bowed. Upper edge of base and posterior margin marked by costa; costa narrow, well-defined, situated on midline. Posterior face delimited by postero -lateral costae; narrow and sharp. Deep, v-shaped grooves between posterior and postero-lateral costae. Lateral faces flat. Antero-lateral costae symmetrically disposed, deflected towards posterior. Anterior face broadly rounded except for depression at antero-basal corner. Anterior face narrower or wider than posterior face.

Approximately 25% of specimens have two secondary costae, situated on posterior face between posterior and postero-lateral costae; secondary costae sharp, less well-defined than other costae, converge on posterior costa at end of base. Basal margin indented between costae.

Comptiform element

Upper edge of base straight, curving round very gradually into posterior margin of cusp. Cusp more proclined than other elements. Posterior margin marked by costa; narrow, well-defined, flat-sided, may be extended postero-basally. Element bowed. Outer lateral face bears three strongly developed, sharp costae positioned at upper outer edge, centre and lower outer edge of outer lateral face, directed posteriorly, laterally and antero-laterally respectively. Central, or more rarely upper, costa may be bifid. Anteriormost costa marks outer antero-lateral corner. Fifth costa marks inner antero-lateral corner; costa directed laterally. Thus, five costae situated in inner antero-lateral, posterior and upper, central and lower outer antero-lateral positions. Anterior face narrow, rounded and twisted with cusp.

Remarks: Ethington and Clark (1982, pl. 13, Fig. 12, text-Fig. 34) described a fifth element, with anterior and posterior keels and asymmetrical lateral costae. It corresponds to a quadricostate element in T. australis figured by Serpagli (1974, pl. 19, Fig. 7, pl. 29, Fig. 15) but is not present in the Greenland collections.

The apparatus of T. comptus described here does not agree with the interpretation of Kennedy (1980) who considered it to be bimembrate possessing only symmetrical and asymmetrical quinquicostate elements. Ethington and Clark (1982) and Repetski (1982) have figured the tricostate and quadricostate elements.

Kennedy (1980) distinguished between T. comptus and T. australis on the basis of apparatus structure. T. australis having numerous, variably costate forms and T. comptus being bimembrate. Since T. comptus is now known to have a more complex apparatus, other criteria must be used. One major distinction is that the costae of T. australis are much more strongly developed and occasionally bear small, serrate denticles. A further difference is the presence of both laterally expanded and compressed asymmetrical quinquicostate elements in T. australis, but only compressed versions in T. comptus. The symmetrical quinquicostate element of T. comptus has a sub-quadrate basal outline whereas that of T. australis is more pentagonal. White matter is more extensive in T. australis, only the basal cavity being hyaline whereas in T. comptus the proclined part of the base is hyaline. A possible distinction may also be the ratio of tricostate to quinquicostate elements. T. australis specimens from the Cape Weber Formation show a ratio of 3:1 and Serpagli (1974) recorded a ratio of 2:1 in the San Juan Limestone whereas the ratio is reversed with tricostate elements outnumbered by quadricostate elements in T. comptus from the Ibex area (Ethington and Clark, 1982) and Greenland.

Several specimens have been erroneously identified as T. comptus by previous authors. These were discussed by Kennedy (1980) who tentatively included some specimens described as Acodus deltatus longibasis and Acodus transitans by McTavish (1973, pl. 1, Figs 17, 23). The morphology of the former is not consistent with other elements of the apparatus and the inclusion of A. transitans must remain questionable. Abaimova (1975) illustrated and described a number of elements as Scolopodus pseudoquadratus. These belong to a variety of taxa, none of which is T. comptus.

Ethington and Clark (1982) considered Scolopodus sexiplicatus Jones and S. aff. S. cornutiformis (Branson and Mehl) of Cooper and Druce (1975) to be synonymous with T. comptus. The figured specimen of S. sexiplicatus may be an asymmetrical quinquicostate element but that of S. aff. S. cornutiformis is too recurved and does not belong in T. comptus.

Range: T. comptus ranges from the base to 121 m in the Wandel Valley Formation in Peary Land and from the base to 200 m in the same formation in Kronprins Christian Land. The species has a range of 164 to 976 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 36 tricostate, 34 quadricostate, 45 symmetrical quinquicostate, 44 comptiform.

Tropodus? sp. nov. A.

Pl. 17, Figs 1 - 7

1974 "Scolopodus" sp. 1; Serpagli, p. 37, pl. 18, Figs 8a-d, pl. 28, Fig. 11.

Remarks: Only t and u elements were recovered, tricostate or quadricostate s elements being absent from the collection. An erect quinquicostate element occupies the u position and differs from its counterpart in T. comptus in being more antero-posteriorly compressed and having narrower lateral faces. The t element is proclined and has a broadly rounded anterior face which curves evenly into the gently convex outer lateral face. The postero-lateral face is convex, multiply costate and bounded by low, sharp costae in antero-lateral and posterior positions. The transition between the two elements is smooth, with transitional specimens having the general morphology of a t element but with one or two prominent costae on the outer face. The elements recovered conform with the diagnosis of Tropodus (Kennedy, 1980) but the inclusion is questioned due to the lack of s elements. The collection is, however, largely from a single sample.

The specimen figured as "Scolopodus" sp. 1 by Serpagli (1974) corresponds to the symmetrical quinquicostate u element.

Range: From 130 to 200 m above the base of the Wandel Valley Formation in Kronprins Christian Land and at 128 m above the base in Borglum Elv.

Number of Specimens: 47

Tropodus sp. B.

Pl. 17, Figs 8,9

Description: Upper edge of base long, sharp, may be produced as short, adenticulate posterior process, curves very gently into posterior margin of proclined cusp. Posterior margin keeled. Anterior margin keeled, turned inwards, produced basally as adenticulate anticusp. Outer face broadly convex, one or two medial costae running full length or dying out distally. Inner face concave, median carina, often a sharp, low costa posterior of midline and carina directed postero-laterally, decreasing in height distally; lateral costae produced as short adenticulate processes. Element bowed inwards.

Basal outline roughly quadrate, narrowest antero-laterally. Basal cavity moderately deep, conical, occupies carinate part of cusp, anterior parallel to anteriormargin of carina, posterior concave to cavity, apex near anterior margin of carina. Albid in all but basal area.

Remarks: The elements agree with the diagnosis of Tropodus (Kennedy, 1980) in being keeled, with elongate bases and slightly arcuate cusps. Only two distinct element types were recovered, one bearing a single median costa on the outer face and the other with two outer lateral costae. The principal variation from element to element is in the prominence of the costa on the inner carina, the degree of convexity of the outer face and the prominence and persistence of the outer lateral costa in unicostate elements.

Range: From 130 to 200 m above the base of the Wandel Valley Formation in Kronprins Christian Land and 992 m above the base of the Cape Weber Formation on Ella Ø.

Number of Specimens: 22

Genus ULRICHODINA Furnish, 1938

1933 Ulrichodina Furnish, p. 334

Type Species: Acontiodus abnormalis Branson and Mehl, 1933

Remarks: Sweet and Bergström (1972) were the first to interpret the apparatus of Ulrichodina and considered it to be unimembrate. The only unimembrate apparatuses in the scheme of Barnes et al. (1979) are Types IC and IIC; the former is more likely for Ulrichodina since the genus is coniform. Bergström (1981) placed Ulrichodina within the monotypic Ulrichodinidae.

Ulrichodina abnormalis (Branson and Mehl, 1933)

Pl. 17, Figs 14 - 18

* 1933 Acontiodus abnormalis, Branson and Mehl, p. 57, pl. 4, Fig. 25 only.

1938 Ulrichodina prima, Furnish, p. 335, pl. 41, Figs 21, 22, text-Fig. 1A.

1944 Ulrichodina abnormalis (Branson and Mehl); Mehl and Ryan in Branson, p. 45, pl. 6, Figs 4-8.

1965 Ulrichodina cristata, Harris and Harris, p. 40-41, pl. 1, Figs 5a-d.

1971 Ulrichodina prima Furnish; Greggs and Bond, p. 1469-1470, pl. 2, Fig. 11.

1971 Ulrichodina sp.; Ethington and Clark, pl. 2, Fig. 25 only.

1977 Ulrichodina prima Furnish; Barnes, p. 104, pl. 1, Figs 9, 10.

1980 Ulrichodina prima Furnish; Grether and Clark, pl. 1, Figs 4, 5.

1980 Ulrichodina abnormalis (Branson and Mehl), Kennedy, p. 67, pl. 2, Figs 28-30, (synonomy to 1978)

1982 Ulrichodina abnormalis (Branson and Mehl); Ethington and Clark, p. 112, pl. 12, Fig. 31.

1982 Ulrichodina cristata Harris and Harris; Ethington and Clark, p. 112-113, pl. 12, Figs 22, 30.

1982 Ulrichodina abnormalis (Branson and Mehl), Repetski, p. 53-54, pl. 26, Fig. 9.

1982 Ulrichodina sp.; Stouge, pl. 3, Fig. 1.

1983 Ulrichodina sp.; Stouge, pl. 3, Fig. 12.

Remarks: Despite the observation by Lindström (1964) that U. prima is a junior synonym of U. abnormalis, most occurrences, until recently, have been reported as U. prima. The possible inclusion of the anteriorly keeled U. cristata was first noted by Barnes and Tuke (1970) and the species was treated as a junior synonym by Greggs and Bond (1971). After studying the types, Repetski (1982) also considered them synonymous.

The Greenland material contains both anteriorly rounded and keeled forms. The keel takes the form of a narrow, sharply rounded costa flanked by longitudinal, shallow grooves. Upon reaching the basal deflection the keel dies out or, in a few large specimens, is deflected to one side and fades out on one of the projecting antero-lateral corners. The presence of this keel in some specimens supports the inclusion of U. cristata as a junior synonym.

Very large specimens tend to have muted costae and grooves, although retaining the chracteristic cross-section. The postero-lateral faces of some specimens are striate.

The largest collection of U. abnormalis (GGU 226394, 33 specimens) contains specimens typical of the species but also some which are shorter and have a more triangular outline. In all other features including cusp cross-section and basal outline these elements are the same as the more common forms. Further work with large collections may establish this as a second element in the U. abnormalis apparatus.

Range: U. abnormalis occurs from 164 m to 868 m in the Cape Weber Formation on Ella Ø; from the base to 140 m in the Wandel Valley Formation in Kronprins Christian Land and from the base to 30 m in the Wandel Valley Formation in Børglum Elv.

Number of Specimens: 58

Ulrichodina wisconsinensis Furnish, 1938

Pl. 17, Figs 17, 18

*	1938	Ulrichodina wisconsinensis, Furnish, p. 335, pl. 41, Figs 19, 20, text-Fig. 1B.
	1967	Ulrichodina wisconsinensis Furnish; Igo and Koike, p. 26, pl. 3, Fig. 14, text-Fig. 5B.
	1968	Ulrichodina wisconsinensis Furnish; Mound, p. 421, pl. 6, Figs 71, 74, 75.
?non	1971	Ulrichodina wisconsinensis Furnish; Jones p. 71, pl. 7, Figs 11, 12.
p	1980	Ulrichodina wisconsinensis Furnish; Grether and Clark, pl. 1, Figs 3, 12 (non Fig. 13).
	1982	?Ulrichodina wisconsinensis Furnish; Ethington and Clark, p. 113-114, pl. 13, Fig. 15.
	1982	Ulrichodina wisconsinensis Furnish, Repetski, p. 55, pl. 26, Fig. 8, text-Fig. 87.
	1982	Ulrichodina wisconsinensis Furnish; Moskalenko, p. 143-44, pl. 28, Fig. 2.

Remarks: The specimens closely fit the description of the type species, having an early rounded cusp, widest just behind the rounded anterior margin and narrowing to a posterior keel. Repetski (1982) noted a slightly inflated anterior margin in some specimens with a shallow groove on the lateral faces just anterior to the midline. This feature is seen on some of the Greenland specimens.

The antero-basal deflection may be a true depression or may be a downward extension of the anterior margin which is folded back underneath the basal cavity.

Range: From the base up to 200 m in the Wandel Valley Formation in Kronprins Christian Land and in one sample 128 m up the Wandel Valley Formation in Peary Land. The species was not found on Ella Ø.

Number of Specimens: 11

Ulrichodina sp. nov. A.

Pl. 17, Fig. 19

Description: Upper edge of base very short, meeting posterior margin of cusp at 160°. Posterior margin straight and keeled. Anterior margin straight, anterior face flat with central, narrow groove. One third of the way towards the posterior, each lateral face bears a narrow, rounded costa. Anterior face separated from lateral costae by a shallow groove. Antero-basal angle 60°, postero-basal angle 60°.

Base short, flared. Basal margin straight, indented at base of anterior face. Basal outline sub-circular, pinched posteriorly near keel. Cavity shallow, slightly concave; very small apex centrally situated just anterior to lateral costae.

Remarks: The species differs from U. abnormalis in having a flat anterior face with a narrow central groove and the narrow lateral costae.

Range: The single specimen was recovered 167 m from the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 1

Ulrichodina sp. nov. B.

Pl. 17, Fig. 20

? 1971 Ulrichodina sp.; Ethington and Clark, pl. 2, Fig. 18.

1982 Ulrichodina n. sp. 3; Repetski, p. 56, pl. 26, Fig. 7, text-Fig. 8H.

Description: Upper edge of base short, curving evenly round into posterior margin; angle between posterior margin and base approximately 135°. Posterior and anterior margins straight, keeled. Cusp biconvex, strongly laterally compressed.

Base short, flared, particularly at the antero-lateral corners. Anterior edge of base depressed, anterior keel runs down depression. Basal cavity opens wide to posterior. Basal margin convex, basal outline sub-rectangular. Lateral edges plicate. Apex situated immediately posterior to antero-basal deflection. Posterior margin of cavity convex (to cavity). Posteriormost part of cavity higher than apex.

White matter fills all but edges of basal cavity and all of anterior keel.

Remarks: The species is unusual for Ulrichodina in being entirely albid, but is placed in this genus owing to the characteristic antero-basal deflection. The specimen figured by Ethington and Clark (1971) is very close in overall morphology but they provided no description. Ulrichodina n. sp. 3 of Repetski (1982) has a similar lanceolate cusp cross-section and a similar antero-basal depression but the posterior basal margin is not open and no mention is made of white matter. Nowlan (1976) described a species of Ulrichodina from the Canadian Arctic which is very similar to U. sp. nov. B. in white matter distribution but has a different cusp cross-section, being rounded anteriorly. U. sp. nov. B. is also similar to Ulrichodina? simplex Ethington and Clark (1982) but has a much more strongly developed ulrichodinid depression.

Range: From 195 to 200 m above the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 2

Ulrichodina sp. C.

Pl. 17, Fig. 21

1980 Ulrichodina wisconsinensis Furnish; Grether and Clark, pl. 1, Fig. 13.

Remarks: The element is generally similar in its morphology to U. wisconsinensis but it lacks the antero-basal depression and, more significantly, the posterior margin bears a single, laterally compressed denticle which is of greater reclination than the cusp. The specimen illustrated by Grether and Clark (1980) has the denticle at a greater angle to the posterior margin than the single specimen from the Wandel Valley Formation.

Range: U. sp. C. was found 3 m above the base of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 1

Genus UTAHCONUS Miller, 1980

1980 Utahconus Miller, p. 436

Type Species: Paltodus utahensis Miller, 1969

Utahconus? bassleri (Furnish, 1938)

Pl.17, Figs 22, 23

* 1938 Paltodus bassleri, Furnish, p. 331, pl. 62, Fig. 1.

1938 Paltodus variabilis, Furnish, p. 331, pl. 42, Figs 9, 10, text-Fig. 1E.

1971 Scolopodus asymmetricus, Druce and Jones, p. 89-91, pl. 19, Figs 3a-7c, text-Fig. 306.

p 1981 Utahconus? bassleri (Furnish); Landing and Barnes, p. 1622, 1624, pl. 1, Figs 9, 11, 19, 21 only, pl. 3, Figs 14, 15, 17 only, pl. 4, Fig. 15, text-Fig. 3. 10, 12, 14, 15, 24 only.

1982 "Paltodus" bassleri Furnish; Ethington and Clark, p. 74-75, pl. 8, Figs 11, 12, (synonomy to 1978)

? 1983 Paltodus bassleri? Furnish; Miller and Dockum, Fig. 2 C, D, E.

Remarks: P. bassleri and P. variabilis of Furnish (1938) were considered by Sweet and Bergström (1972) to be members of the same apparatus as Acodus oneotensis Furnish and Oistodus triangularis

Furnish. This reconstruction has been supported by Lindström (1977), who also included specimens referred to Oistodus inclinatus Branson and Mehl by Furnish (1938), and by Landing and Barnes (1981) who included Scolopodus sulcatus Furnish. These reconstructions were dismissed by Ethington and Clark (1982) who considered the apparatus to consist of an essentially monoelemental symmetry transition from P. bassleri to P. variabilis. The former name is the one selected from the species by Druce and Jones (1971) as first revisors. Scolopodus asymmetricus Druce and Jones was included as a junior synonym by Ethington and Clark (1982). The collection of U? bassleri from the Cape Weber Formation is small, but no specimens of A. oneotensis or O? triangularis were recovered and the concept employed by Ethington and Clark (1982) is followed here.

Utahconus was erected by Miller (1980) to include apparatus with unicostate and bicostate albid elements. The assignment of bassleri to the genus is queried because symmetrical variants are common, compared with their rarity in the type species; conversely unicostate elements are rare in U? bassleri.

Range: U? bassleri occurs up to 46 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 24

Genus *WANDELIA* gen. nov.

Type Species: *Wandelia fuscina* sp. nov.

Derivation of Name: After the Wandel Valley Formation.

Diagnosis: Apparatus trimembrate, comprising an Sa element with a single denticle symmetrically disposed either side of the cusp, an Sb element with the denticles asymmetrically disposed and an Sc element with a single denticle posterior to the cusp.

Remarks: The elements are similar to those of *Multioistodus* Cullison but the apparatus structure differs significantly since it lacks the Sd element, which has two lateral denticles and a posterior denticle. The M element present in species here described as *Multioistodus?* is also not represented in the apparatus.

Ethington and Clark (1982) considered that the apparatus was probably referable to a new genus but were uncertain if the full apparatus was represented in their single sample. A comparable number of elements of *W. fuscina* has been recovered over a wider stratigraphic range in Greenland and no additional members of the apparatus are recognised.

White matter distribution in the genus appears to be a little variable; most, although not all, specimens of *W. fuscina* are albid but some just have albid growth axes. All elements of *W?* sp. nov. A. are hyaline.

Wandelia fuscina sp. nov.

Pl. 18, Figs 1 - 6

1969 Erismodus sp.; Bradshaw, p. 1150, pl. 136, Fig. 1, text-Fig. 3G.

1982 ?New Genus 4; Ethington and Clark, p. 119-20, pl. 16, Figs 1-3.

Derivation of Name: Fuscina (L.), three-pronged fork, trident.

Diagnosis: A specis of Wandelia with long, slender denticles and cusp, both of strongly biconvex cross-section. Basal cavity broad and open.

Description:

Sa element

Cusp erect, anterior face broadly rounded, terminated by median lateral costae, posterior face more convex, bordered by narrow groove at junction with lateral costae. Lateral costae produced as denticles, postero-laterally directed, antero-posteriorly compressed with sharp median costae. Upper surface of base rounded.

Basal margin straight or incised into upper edge of base. Basal outline sub-circular to triangular. Basal cavity conical with narrow grooves along line of lateral denticle; apex near anterior margin.

Sb element

Cusp erect, twisted so that lateral costae are antero-lateral and postero-lateral in position. Anterior face broadly rounded; posterior face more convex with narrow grooves just posterior of lateral costae. Antero-lateral costa produced as denticle, proclined, antero-laterally compressed with sharp edges. Postero-lateral costa produced as denticle, compressed, with plane of compression postero-lateral, sharp-edged, slightly more erect than cusp, situated closer to cusp than antero-lateral denticle.

Upper surface of base rounded, basal margin straight, basal outline sub-circular, elliptical, or pinched where lateral costae meet basal margin. Basal cavity approximately conical, some large specimens have a faint anterior groove; apex near anterior margin.

Sc element

Cusp erect, outer face broadly rounded, inner face more sharply convex. Anterior margin sharp, distally keeled; keel deflected inwards at point of maximum recurvature, narrow groove just posterior to deflection on inner face. Posterior margin sharp, narrow grooves may be present just anterior to margin. No denticle at termination of anterior margin. Posterior margin joins posterior denticle at acute angle, denticle may be posterior, creating sub-symmetrical element, or postero-lateral with cavity opening inwards.

Basal margin straight to gently convex, basal outline elliptical in sub-symmetrical forms, sub-circular in asymmetrical forms; apex near anterior margin.

White matter variable in development, in all elements, from very thick strands along the growth axis and denticles to totally albid cusp and denticles.

Remarks: An Sc element of W. fuscina was figured by Bradshaw (1969) and the full apparatus illustrated by Ethington and Clark (1982). The transition between elements of the apparatus is gradational; the denticles of the Sa element become increasingly asymmetrical and the denticle of the Sc element shifts from a postero-lateral to a posterior position: There are some breaks in the transition series, since none of the Sc elements with antero-lateral denticles reported by Ethington and Clark (1982) are present in the Greenland collections.

Range: From 107 to 38 m below the top of the Wandel Valley Formation in western Peary Land and from 118 m to 17 m below the top in central Peary Land. On Albert Heim Bjerge it occurs from the base to 268 m in PF 770713-1.

Number of Specimens: 22 Sa, 35 Sb, 83 Sc.

Wandelia? sp. nov. A.

Pl. 18, Figs 7 - 11

Description:

Sa element

Element wider than long. Cusp short, reclined, rounded in cross-section, lateral costae situated in an antero-lateral position. Denticles broad, erect, very short, antero-posteriorly compressed. Triangular in outline.

Basal margin straight, basal outline a wide triangle with apex posterior. Basal cavity very shallow, apex central.

Sb element

Cusp short, reclined, rounded in cross-section, bearing sharp antero-lateral costae. Base of lateral denticles broad, denticles triangular in outline, erect, very short, one is upwardly directed, the other outwardly with cusp deflected towards the latter denticle.

Basal margin sinuous, basal outline an antero-posteriorly compressed trough widest below cusp. Basal cavity shallow, apex central.

Sc element

Cusp short, reclined; anterior face rounded; lateral faces flat, one lateral face bears antero-lateral costa; posterior margin sharp. Posterior denticle laterally compressed, half height of cusp.

Basal margin straight, basal outline ovate; basal cavity shallow, apex anterior.

Remarks: The species has only been described previously from the eastern Canadian Arctic Islands by Nowlan (1976) in an unpublished PhD thesis. Based on a collection of approximately 20 specimens, he reconstructed the apparatus and included the three element types described above. The Sc element in his material is described as sometimes having an anterior denticle, although this morphology is not seen in the Greenland material.

The Sa and Sb elements are superficially similar in their cusp and denticle morphology to *Tricladiodus clypeus* Mound but lack the third, posterior, process. The apparatus is similar to that of *W. fuscina* although the chracteristic fin-shaped denticles and hyaline nature serve to distinguish it. The assignment to *Wandelia* is tentative because dolabrate forms described by Nowlan (1976) could prove to be Sc and M elements; this would make the apparatus more similar to that of *Multioistodus*, although still lacking an Sd element.

The specimens described as *Tricladiodus aurilobus* by Lee (1975) are very similar to the Sa and Sb element of *W?* sp. nov. A. but differ in having a basal cavity that is confined to the base of the cusp, and in possessing denticles of rounded profile.

Range: Found at 30 m below the top of the Wandel Valley Formation in Kronprins Christian Land.

Number of Specimens: 9 Sa, 7 Sb, 4 Sc.

Genus *WEBERINA* gen. nov.

Type Species: *Weberina guyi* sp. nov.

Derivation of Name: After the Cape Weber Formation of East Greenland.

Diagnosis: The apparatus is monoelemental comprising a squat coniform with a cusp which is very reduced or absent. All species are transversely costate. Basal cavity very shallow and may be reduced to a narrow, shallow slit.

Remarks: The genus is a very rare component of upper Ibexian faunas. Only *Weberina guyi* has previously been figured (as *Scolopodus?* n. sp. C. Stouge, 1982). The distribution seems to be restricted to what is now the northern part of the Midcontinent Province.

Weberina superficially resembles *Clavohamulus* Miller but is distinguished by being costate or striate rather than having a surface sculpture of fine, granular nodes. The elements of *Weberina* are, additionally, not always bilaterally symmetrical. The two genera are interpreted here as structural homeomorphs.

Specimens of *Oneotodus costatus* from Kronprins Christian Land have morphologies which are transitional to *W. guyi*. The cusp is reduced in length and girth and is more recurved and there is an associated elongation of the basal outline. Such a morphology is quite close to that of W. guyi but the two cannot be considered congeneric. The emended diagnosis of Ethington and Brand (1981) for Oneotodus include coniforms with stout albid cusps of subcircular or ellipsoidal cross-section, circular to ovoid basal outline and a basal cavity of asymmetrical triangular shape in lateral profile. Without further emending the diagnosis, W. guyi and W. candidisphaera cannot be included in Oneotodus. O. costatus may be the ancestor of the oldest known Weberina, W. guyi.

Weberina guyi sp. nov.

Pl. 18, Figs 12 - 14

1982 Scolopodus? n. sp. C.; Stouge, p. 44, pl. 3, Figs 16-18.

1983 Scolopodus? n. sp.; Stouge, p. 13, Fig. 3.

Derivation of Name: In memory of the late Peter J. Guy.

Diagnosis: Cusp much reduced in size or almost absent, the element is strongly costate. A furrow between the lateral, transverse costae runs down the midline of the element or obliquely across it. The anterior margin is recurved through up to 90° so that it may be parallel to the basal margin. Basal cavity is small; with a very small apex situated anteriorly.

Description: The cusp is very short, and poorly developed in relation to the rest of the element. Anterior of element is rounded. The antero-basal angle is 90° and the anterior margin is recurved through up to 90°. The lateral faces bear up to 8 (usually 3 - 4) costae which have steep anterior facets and gently sloping posterior facets. These continue across the anterior face where a furrow separates the two sets. Near the furrow the costae are deflected to the posterior. The furrow may run down the midline or obliquely across it. The costae die out before reaching the basal margin and, on the lateral faces, may slope towards the anterior. A posterior face is defined by the two posteriormost costae and is recessed between them. The surface is flat or slightly convex.

The basal margin is straight to mildly convex. The basal outline is ovate. The basal cavity is a longitudinal trough, open at the posterior, and parallel-sided or narrowing towards the anterior, deepest at the anterior, where the very small apex is situated. The anterior margin of the cavity is rounded.

All but the most basal part of the element is albid.

Remarks: The species has been figured previously by Stouge (1982) who reported it as a species of *Scolopodus?*. *W. guyi* does not however conform to the apparatus plan of *Scolopodus sublaevis* Pander, the type species, as determined by Fåhraeus (1982). The specimen figured by Stouge has rather more costae than the Greenland specimens.

Range: *W. guyi* occurs in a single sample 9 m up the Wandel Valley Formation in Peary Land but occurs between 20 and 103 m in Kronprins Christian Land. The species has a range of 737 - 868 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 31

Weberina candidisphaera

Pl. 18, Figs 15 - 18

Derivation of Name: candidus, white (L); sphaera globe (L).

Diagnosis: The element consists of an albid, spherical body and a base which slopes inwards from the base of the sphere. The basal cavity is shallow and slit-like. The spherical body is tranversely costate with numerous, thin serrate costae.

Description: The spherical body bears multiple rows of thin, serrate costae which are directed posteriorly and increase in length towards the posterior. There is a small posterior face which may take the form either of a flat area or a furrow.

The base slopes inwards from the spherical body and the anterior margin slopes towards the posterior. The basal cavity is a narrow slit, deepest anteriorly then shallowing rapidly towards posterior. The base is hyaline and the spherical body entirely albid.

Remarks: W. candidisphaera differs from W. guyi in having finer costae which are much more numerous, lower in relief and tend to be serrate. The basal cavity is slit-like with the base sloping inward whereas in W. guyi the cavity is broad and very shallow.

The single occurrence of W. candidisphaera is above the range of W. guyi on Ella Ø and it may represent a continuation of the trends seen between O. costatus and W. guyi. There is a reduction in the dimensions of the basal cavity and the cusp is entirely absent.

Range: The specimens were found in a single sample 976 m up the Cape Weber Formation.

Number of Specimens: 11

Weberina sp. A.

Pl. 18, Fig. 19

Description: The anterior and lateral areas of the element are costate with thin, serrate costae of moderate relief running transversely across the cusp. There is no median furrow. The posterior face is recessed and concave. There is no cusp.

The basal cavity is approximately ⅓ the width of the element and is parallel-sided. The tiny apex is situated anteriorly and the cavity shallows to the posterior. A rim surrounds the anterior part of the basal margin.

Remarks: The morphology of Weberina sp. A. is intermediate between that of W. guyi and W. candidisphaera. The overall shape is that of W. guyi but the costae and lack of cusp are more akin to W. candidisphaera. The basal cavity is of intermediate width.

Range: The single sample containing *W.* sp. A. was from 103 m up the Wandel Valley Formation.

Number of Specimens: 1

Genus GEN. NOV. A

1982 New Genus 2, Ethington and Clark

Gen. nov. A. sp. nov. A.

Pl. 18, Figs 20 - 23

? 1982 New genus 2; Ethington and Clark, p. 117, pl. 13, Figs 18-20, 24.

<u>Description</u>:

<u>Coniform element A</u>

Upper edge of base not discernable from posterior margin. Posterior margin sharp, evenly and gently curved. Anterior margin flat to very broadly rounded, terminated by low antero-lateral costae. Lateral faces slightly convex.

Basal margin straight. Basal outline triangular, apex posterior. Basal cavity shallow.

<u>Coniform element B</u>

Upper edge of base of medium length, convex, sharp. Posterior margin straight, sharp. Anterior margin flat to very broadly rounded, terminated by antero-lateral carinae. Lateral faces flat.

Base unexpanded, basal margin flat. Basal outline sub-triangular, modified anteriorly, apex of triangle posterior.

Pastinate element A

Anterior margin rounded. Anterior process high, sharp, tapering gradually to posterior, one-third total length of element. Cusp short, inner face flat, outer face convex, convexity continued across base as sharp, prominent lateral process. Posterior process commences lower than anterior process/cusp junction, sharp, tapering to posterior. Posterior margin sharply rounded. Processes have fused, incipient denticles one quarter the process height. Element twisted along its length.

Basal cavity very shallow and broad below anterior process, narrow and slit-like below lateral and posterior processes.

Pastinate element B

Anterior process bears single, rounded denticle almost as high as cusp, inner side of denticle bears small, subsidiary denticle just below apex. Cusp short, biconvex, lateral process very small and limited to basal margin. Posterior process tapers rapidly, upper edge almost meeting basal margin.

Basal cavity shallow, broad below anterior process and cusp, narrow under lateral process, absent under posterior process.

All elements albid.

Remarks: These elements are broadly similar to those recorded as New Genus 2 by Ethington and Clark (1982) but they have not been reported elsewhere in the literature. One specimen figured by Ethington and Clark (1982, pl. 13, Fig. 18) is closely similar to pastinate element A. The other elements recorded by Ethington and Clark (1982) were not recovered from Greenland and, similarly, those from the Cape Weber Formation are not recorded from Utah. Ethington and Clark had a very small number of specimens and were not sure if they represented a single species, so declined to erect a new genus. The Greenland specimens are close enough in their morphology to be congeneric with those from the Fillmore Formation but the uncertainty about individual species remains. This problem and the lack of specimens again prevents erection of a new genus.

Range: From 190 to 992 m in the Cape Weber Formation on Ella Ø.

Number of Specimens: 2 coniform A, 2 coniform B, 2 pastinate A, 1 pastinate B.

Gen nov. A. sp. nov. B

Pl. 18, Figs 24, 25

Remarks: Only pastinate A and B elements were recovered. They differ from those of Gen. nov. A. sp. A in having a greater height to length ratio, a stouter cusp, much shorter posterior process and a more prominent lateral process, on the pastinate A element, which extends to the full height of the element. Gen. nov. A. sp. nov. B was only recovered from central Peary Land.

Range: Up to 9 m in the Wandel Valley Formation in Børglum Elv.

Number of Specimens: 5 pastinate A, 1 pastinate B.

Genus GEN. NOV. B

Gen. nov. B. sp. nov. A

Pl. 18, Fig. 26

1979 New genus new species; Harris _et al_., pl. 3, Fig. 8.

Remarks: The element is a P element rather similar to those of _Appalachignathus_ and _Bergstroemognathus_ with small, fused denticles and an inwardly flared basal cavity. It was first described from the Champlain Valley by Raring (1972) in an unpublished PhD thesis and has only been figured subsequently by Harris _et al_. (1979). Collections at hand are insufficient to erect a new genus or species. It may, however, be noted that no ramiform elements have been recorded in association although in Greenland this may be due to the small collections.

Smaller specimens in the collection tend to have more rounded denticles and a less prominent cusp.

Range: 298 to 528 m above the base of section PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 5

Genus GEN. NOV. C

Gen. nov. C. sp. nov. A

Pl. 18, Figs 27, 28

Remarks: A single sample from the Heim Bjerge Formation contains two specimens of highly characteristic morphology. The element is albid, highly laterally compressed and the cusp is spatulate. Denticles are small and confluent, with only the denticle tips discrete. Posterior to the denticles the posterior margin curves evenly round to the posterior extremity of the basal cavity. The element is bowed slightly inwards and the narrow, shallow basal cavity is also strongly turned inwards.

Range: Found at 410 m above the base of PF 770713-1 on Albert Heim Bjerge.

Number of Specimens: 2

CHAPTER 5

BIOSTRATIGRAPHY

5.1. DEVELOPMENT OF CONODONT ZONATION FOR THE IBEXIAN AND WHITEROCKIAN OF THE MIDCONTINENT PROVINCE

The first attempt at producing a conodont biozonation of the Lower Ordovician was that of Ethington and Clark (1971). Prior to this there had been only seven systematic descriptions of Ibexian faunas and correlations had principally been based on simple comparisons with the earlier work of Branson and Mehl (1933) and Furnish (1938). The Lower Ordovician was divided by Ethington and Clark (1971) into five "Faunas", designated A - E, and intended as informal divisions to be used only whilst more data were collected.

Miller (1978) produced a zonation of Upper Cambrian and lowermost Ordovician strata. In this scheme, the uppermost zone, the *Cordylodus proavus* Zone, was divided into five sub-zones, of which the upper two, the *Hirsutodontus simplex* Sub-Zone and the *Clavohamulus hintzei* Sub-Zone, were equivalent to Fauna A; Faunas B - E remained in use, often semi-formally, despite their rather loose definitions.

Systematic descriptions of the faunas of the Ibex area, Utah, were published by Ethington and Clark (1982) together with a refined, although still provisional, zonation of the Ibexian and early Whiterockian. The Ibex area is the designated type area of the Ibexian Series (Ross *et al.*, 1982) and, since the trilobite - brachiopod zones of Ross (1951) and Hintze (1952) are partly based

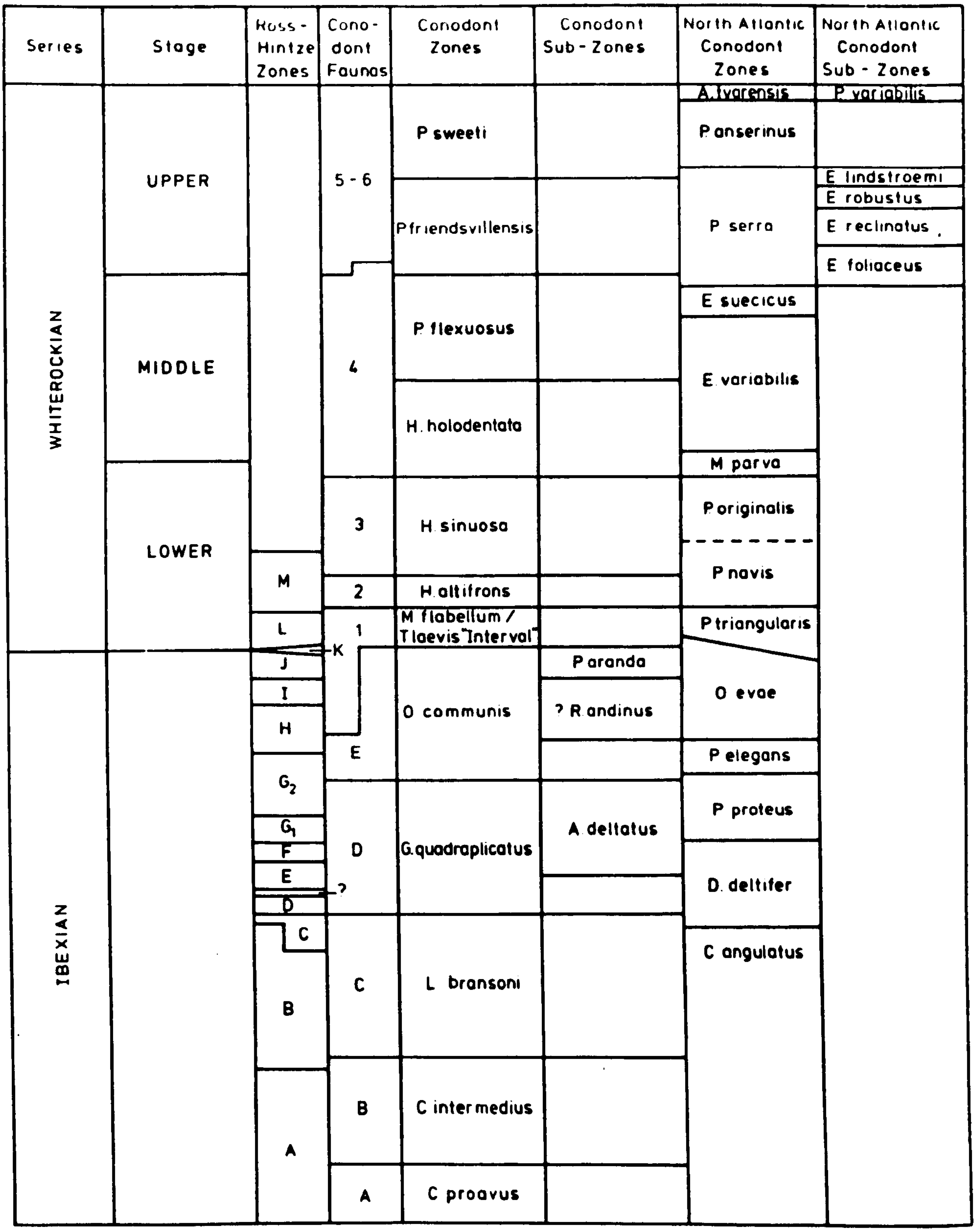


Fig. 5.1 Lower and early Middle Ordovician chronostratigraphic units (left two columns), stages of Whiterockian are after Sweet (1984); shelly fauna biozonation, after Ross et al., 1982 (3rd column); conodont faunas of Ethington & Clark, 1971 (4th column); conodont zones and sub-zones adapted from the Intervals of Ethington & Clark, 1982, and the zones of Sweet, 1984 (5th and 6th columns); "North Atlantic conodont zones and sub-zones of Lindström, 1971, and Bergström, 1971, (6th and 7th columns).

on the same sections, it is possible to correlate directly between these and the "Intervals" of Ethington and Clark (1982). Seven were proposed above the C.proavus Zone in the Ibexian. The lower two, the Cordylodus intermedius and Loxodus bransoni Intervals, are essentially the same as Faunas B and C, although more strictly defined. The major refinement is in Faunas D and E which were separated into two and three Intervals respectively.

The two Intervals equivalent to Fauna D are the Glyptoconus quadraplicatus/aff. Scolopodus rex Interval and the Acodus deltatus/ Macerodus dianae Interval. The base of Fauna E is approximately coincident with the base of the Oepikodus communis/Oepikodus? marathonensis Interval, which is succeeded by the Jumudontus gananda/ ?Reutterodus andinus Interval and the Protoproniodus aranda/Juanognathus jaanussoni Interval. The succeeding Microzarkodina flabellum/Tripodus laevis Interval is considered to be earliest Whiterockian in age (Ethington and Clark, 1982; Ross et al., 1982).

The Ibex area was situated towards the western margin of the North American craton during the Ordovician and passes westwards into clastic and volcanic successions (Ethington, 1979) where the faunas are dominated by deeper water taxa of North Atlantic provincial affinity (Ethington, 1979; Harris et al., 1979). In areas of North America where shallower-water facies than Ibex were present, the faunas tend to be dominated by long-ranging coniform species, examples being the Jefferson City Formation of Missouri (Branson and Mehl, 1933; Kennedy, 1980), the Shakopee Formation of Illinois (Furnish, 1938) and the Wandel Valley Formation. The upper Ibexian

Intervals of Ethington and Clark (1982) are not consistently recognisable in such areas, but two horizons which can usually be recognised are the bases of the G. quadraplicatus/aff. S.rex Interval and the O. communis/O? marathonensis Interval (equivalent to the bases of Faunas Dand E). For these reasons, the zonal scheme used in this study is a modified version of that of Ethington and Clark (1982) but should, hopefully, be applicable to both the deeper water facies of Ibex and the El Paso Limestone (Repetski, 1982) and the shallow-water facies mentioned above.

The zones proposed are essentially the same as Faunas A - E but incorporate the more precise definitions of Ethington and Clark (1982). In addition, the upper five Intervals in the Ibexian are utilised as sub-zones (Fig. 5.1). The C. intermedius and L.bransoni Intervals are retained as zones and their definition is unchanged. The L.bransoni Zone is succeeded by the G. quadraplicatus Zone, the base of which is the same as the G. quadraplicatus/aff. S.rex Interval, defined as the lowest occurrence of G. quadraplicatus. The top of this zone is defined by the first occurrence of O. communis, which marks the base of the O. communis Zone. Thus, the A. deltatus/ M. dianae Intervals forms the later part of the G. quadraplicatus Zone. The base of the Interval was defined by Ethington and Clark (1982) as the lowest occurrences of A. deltatus and it is here termed the A. deltatus Sub-Zone.

The O. communis Zone is divisible into three sub-zones, the lowest of which corresponds to the O. communis/O? marathonensis Interval and is left un-named due to the absence of a second suitable species on which to base it. The succeeding ?R. andinus Sub-Zone equates with the J. gananda/?R. andinus Interval and the P. aranda Sub-Zone with the P. aranda/J. jaanussoni Interval. Both of these sub-zones take the name of the species which Ethington and Clark (1982) used to define their equivalent Intervals.

The first conodont zonation of the post-Ibexian Ordovician was made by Sweet et al. (1971) who erected a sequence of Faunas similar in concept to those of Ethington and Clark (1971) and designated 1 - 12. Subsequent investigations (Ethington and Clark, 1982) have shown that Fauna 1, characterised by J. gananda, P. aranda and M. flabellum, is of predominantly Ibexian age and thus overlaps with the O. communis Zone. The base of the Whiterockian, defined as the base of Ross - Hintze Zone L (Ross et al. , 1982), lies within the upper part of Fauna 1 (op. cit.). Faunas 2 - 6 also lie within the Whiterockian, now redefined (Ross et al., 1982) to include the Chazyan of Sweet et al. (1971). However, many of the Faunas overlap, a problem particularly affecting Faunas 5 and 6, which are almost completely coeval (Sweet, 1984) (Fig. 5.1).

As a continuation of their Ibexian zonation, Ethington and Clark (1982) proposed five Intervals in the Lower and Middle Whiterockian (sensu Sweet, 1984): the M. flabellum/T. laevis Interval, the Pteracontiodus cryptodens, Histiodella altifrons/Multioistodus auritus Interval, the Histiodella sinuosa Interval, the Paraprioniodus costatus/Chosonodina rigbyi/Histiodella holodentata Interval and the ?Phragmodus flexuosus Interval. However, there are two problems which restrict the usefulness of these Intervals:

i) Towards the top of the Ibex succession, quartzite beds are present and the ranges of species in the top two intervals are incompletely known.

ii) The bases of the P. cryptodens/H. altifrons/M. auritus Interval and the P. costatus/C. rigbyi/H. holodentata Interval are both defined where the three named taxa appear at approximately the same horizons. Elsewhere, these groups of species have significantly different ranges (Harris and Repetski, pers. comm.).

Sweet (1984) established, by means of graphical correlation (Shaw, 1964), a series of conodont-based chronozones through the Mohawkian and Cincinnatian Series (Ross et al, 1982) but also listed six zones in the underlying Whiterockian (Fig. 5.1). The lower four zones were not, however, formally defined in terms of Standard Time Units on the Composite Reference Section but since the bases of all succeeding zones were defined by the lowest occurrence of the eponymous species it is likely that this was also the intention for the lower zones. If this is the case, then the lower four zones of Sweet (1984) are approximately equivalent to the upper four Intervals of Ethington and Clark (1982). The zones of Sweet (1984) are here used in preference, since they will eventually form the basis for a Whiterockian shallow-water biofacies zonation (Harris and Repetski, pers. comm.).

There is a taxonomic complication regarding the uppermost zone in the Middle Whiterockian, the P. flexuosus Zone, as there is uncertainty as to whether the apparatus contains a coniform or dolabrate M element (see Chapter 4). Ethington and Clark (1982) described the older, coniform-bearing apparatus as ?P. flexuosus and used the species to define the ?P. flexuosus Interval. Sweet (1984) termed the same, older species P. "pre-flexuosus" and used it as the basis for his highest Whiterockian zone. Both of these zones are therefore based on the same taxon, despite the different names applied. Moskalenko (1982) has established that the older of the species, the coniform-bearing apparatus, should bear the name P. flexuosus and the zone defined by its lowest occurrence is here termed the P. flexuosus Zone.

5.2. BIOSTRATIGRAPHY OF THE CAPE WEBER, NARWHALE SOUND AND HEIM BJERGE FORMATIONS

On Ella Ø, the first occurrence of G. quadraplicatus is at 64 m above the base of the Cape Weber Formation. Below this height the faunas contain taxa characteristic of the L. bransoni Zone (Fig. 5.2); the presence of U? bassleri is particularly significant since this species has not been found above the L. bransoni Zone (Ethington, pers. comm.), U? bassleri is associated with Cordylodus sp. nov. A., "O" triangularis, "Drepanodus" sp. A. and Semiacontiodus sp. A. In contrast, the basal 1 m of the Cape Weber Formation on Albert Heim Bjerge contains G. quadraplicatus, E. parallelus, T. comptus, O. costatus and U. abnormalis (unpubl. GGU collections) indicative of the G. quadraplicatus Zone. This discrepancy is consistent with the diachroneity in the Dolomite Point - Antiklinalbugt Formation boundary described by Kurtz and Miller (1981); on Ella Ø the conodonts were

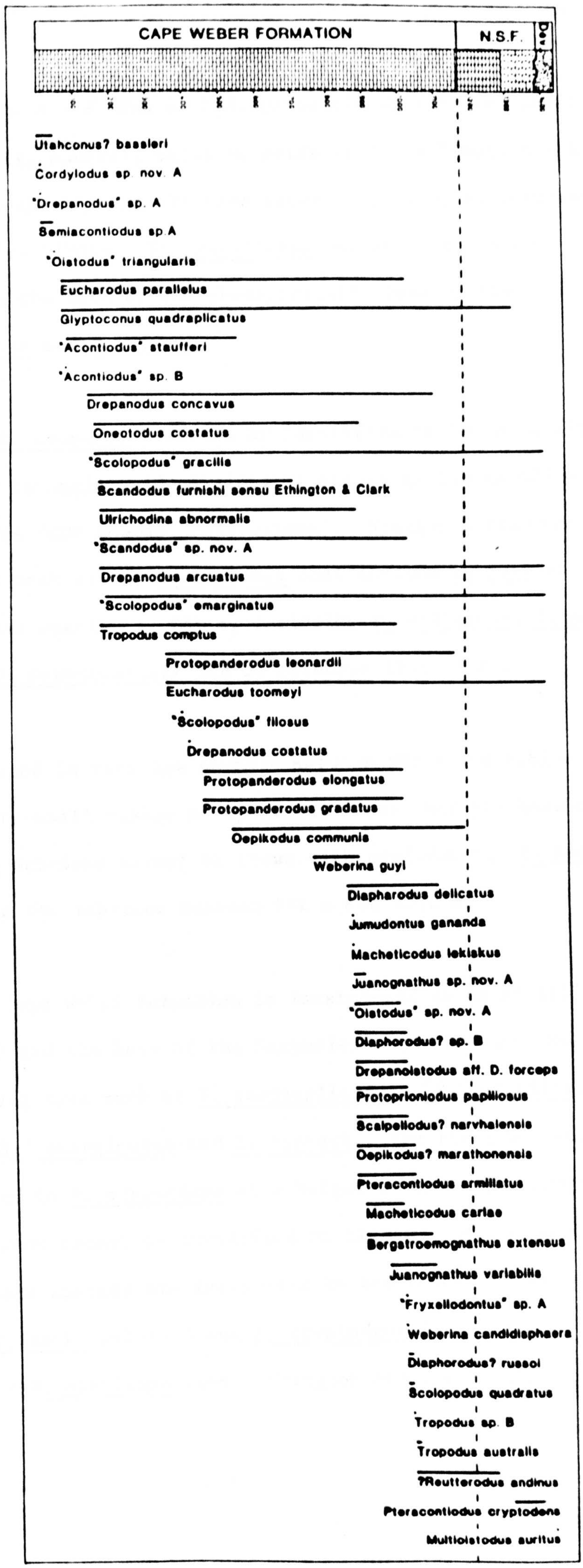


Fig. 5.2 Range chart of taxa in section PF 770824-1, Ella Ø

reported as "Fauna A - B" and on C.H. Ostenfeld Nunatak as "lower Fauna B". There is, however, still no evidence for a "Fauna D - E" boundary close to the base of the Cape Weber Formation, as reported by Kurtz and Miller (1981). The A.deltatus Sub-Zone cannot be identified due to the lack of the characteristic taxa of the sub-zone, A.deltatus and M. dianae.

The base of the O. communis Zone can be identified at 514 m on Ella Ø, but diachroneity is again evident since it occurs as low as 427 m on Albert Heim Bjerge (GGU unpubl. collections). Species introduced within the lower part of the O. communis Zone include W. guyi at 737 m and numerous species at 848 m, including D. delicatus, J. gananda, P. papiliosus, O? marathonensis and B. extensus (Fig. 5.2).

?R andinus is found in very low numbers between 992 m and 1161 m although the very small number of specimens means that the base of the ?R. andinus Sub-Zone cannot be drawn with confidence. T. australis is also found in the sub-zone between 992 m and 1010 m.

The top of the Cape Weber Formation is interpreted to be at 1165 m (see Chapter 3) and the base of the Narwhale Sound Formation contains only long-ranging taxa such as G. quadraplicatus, "S." gracilis, D. arcuatus, "S." emarginatus and E. toomeyi. The first new species to be introduced is P. cryptodens at a height of 95 m and, hence, the P. aranda Sub-Zone cannot be identified on Ella Ø. In the Ibex area only the nominate species are introduced in the lowermost Whiterockian M. flabellum/T.laevis Interval and P. cryptodens is first seen near the base of the H. altifrons Zone (Ethington and Clark, 1982).

Elsewhere, however, P. cryptodens is known to extend to the base of the Whiterockian (Harris and Repetski, pers. comm.) and although the M. flabellum/T. laevis Interval is not recognisable on Ella Ø there is no evidence to suggest that strata of this age are absent. On Albert Heim Bjerge, P. cryptodens is present 716 m above the base of the Cape Weber (GGU unpubl. collection), suggesting that the degree of diachroneity of the Cape Weber - Narwhale Sound Formation boundary is greater than that of the lower boundaries.

A single sample 215 m up the Narwhale Sound Formation contains M. auritus, a species introduced at the base of the H. altifrons Zone in the Ibex area. C. rigbyi is present at 912 m in the Cape Weber Formation on Albert Heim Bjerge and is indicative of an H. altifrons Zone age or younger.

In summary, the base of the Cape Weber Formation on Ella Ø contains L. bransoni Zone conodonts. The base of the G. quadraplicatus Zone occurs at 64 m and the base of the overlying O. communis Zone is at 514 m. The ?R. andinus Sub-Zone can be tentatively identified at 992 m. The lowest Whiterockian conodonts occur 95 m up the Narwhale Sound Formation, although more detailed collecting may indicate a lower position. The youngest Ordovician conodonts preserved on Ella Ø are of the H. altifrons Zone.

On Albert Heim Bjerge, the Ordovician succession is more complete and conodont samples were collected from the upper part of the Narwhale Sound Formation and the Heim Bjerge Formation. From the base of section PF 770713-1, the upper 150 m of the Narwhale Sound

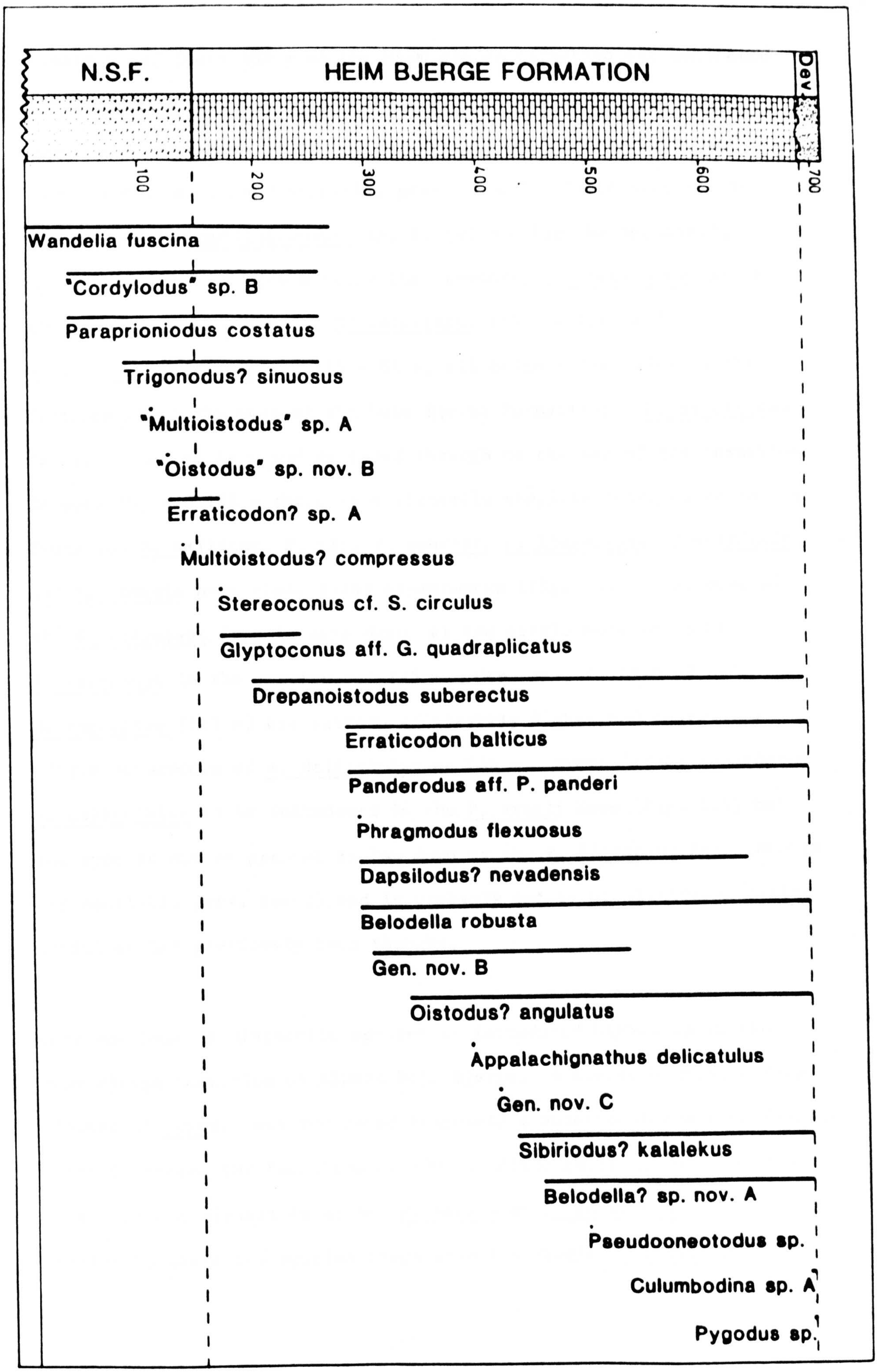


Fig. 5.3 Range chart of taxa in section PF 770713-1, Albert Heim Bjerge

Formation and lower 108 m of the Heim Bjerge Formation are dominated by "Cordylodus" sp. B., P. costatus, T? sinuosus and W. fuscina (Fig. 5.3) indicative of the H. holodentata Zone. (Ethington and Clark, 1982; Harris and Repetski, pers. comm.). These species are accompanied by "Multioistodus" sp. A. (40 m below the boundary), Oistodus sp. nov. B. (26 m below the boundary), Erraticodon? sp. A. (26 m below to 18 m above), M? compressus (14 m below) and G. aff. G. quadraplicatus (18 - 88 m, all heights now refer to the distance above the base of the Heim Bjerge Formation). D. suberectus is first seen at 44 m and is found through to the top of the formation. Between 108 and 138 m there is a virtually complete change-over in the fauna and E. balticus, P. aff. P. panderi, P. flexuosus, D? nevadenis and B. robusta have their first appearances (Fig. 5.3). The base of the P. flexuosus Zone is here drawn at the single occurrence of P. flexuosus in the section, at 138 m. Gen. nov. B. (148 m) and O. angulatus (181 m) are introduced slightly higher and there is a single occurrence of A. delicatulus at 236 m. Sweet (1984) considered A. delicatulus to be introduced in the P. sweeti Zone (Fig. 5.1) but the species may be present as low down as the P. flexuosus Zone (Harris and Repetski, pers. comm.) and is probably not as biostratigraphically useful as has previously been thought.

Only one zonally diagnostic species is introduced higher up in the Heim Bjerge Formation on Albert Heim Bjerge. A single haddingodiform element of Pygodus was recovered immediately underneath the unconformity which truncates the formation at 690 m. Although it is not possible to assign the element to either P. serrus or P. anserinus (see Chapter 4) these two species range from the middle P. flexuosus Zone to the upper P. sweeti Zone (Sweet, 1984) and thus the top of the formation at this locality is of Middle to Upper Whiterockian age (Fig. 5.1).

On C.H. Ostenfeld Nunatak, the Heim Bjerge Formation has been estimated to be 1200 m thick (Frykman, 1979), an extra 500 m being preserved underneath the unconformity in comparison with Albert Heim Bjerge. The upper 100 m were sampled at 10 m intervals for conodonts and yielded the taxa shown in Fig. 5.4. The faunal list is essentially the same as that found in the upper part of the Heim Bjerge Formation on Albert Heim Bjerge with the exception of a single pygodiform element of P. anserinus, which indicated a position within the P. sweeti Zone (Fig. 5.1) which is of upper Upper Whiterockian age. The occurrence of P. anserinus implies that the upper 500 m of the Heim Bjerge Formation at this locality were deposited in a very short timespan in the Upper Whiterockian. However, it is also possible that there is unrecognised faulting and repetition in the Heim Bjerge Formation on C.H. Ostenfeld Nunatak. At present it is not possible to decide between the two possibilities and more detailed mapping and collecting will be required to fully resolve the problem. Nevertheless, the youngest sediments identified to date in the Caledonides of Central East Greenland are of uppermost Whiterockian age, with no evidence for the younger rocks speculated to be present by Peel (1982b).

Amorphognathus? sp.A

Appalachignathus delicatulus Bergstrom *et al.*

Belodella robusta Ethington & Clark

Belodella? sp. nov.A

Belodina monitorensis Ethington & Schumacher)

cordylodiform 1

Culumbodina sp.A

Dapsilodus? nevadensis (Ethington & Schumacher

Drepanoistodus suberectus (Branson & Mehl)

Erraticodon balticus Dzik

Oistodus? angulatus Bradshaw

Oulodus sp. nov. A

Panderodus aff. P.panderi (Stauffer)

Pygodus anserinus Lamont & Lindstrom

Sibiriodus? kalalekus sp.nov.

Fig. 5.4 List of taxa in section PF 770723-1, C.H. Ostenfeld Nunatak

5.3. BIOSTRATIGRAPHY OF THE WANDEL VALLEY FORMATION

Taxa present in the Ibexian part of the Wandel Valley Formation are predominantly long-ranging, hyaline coniform species although a small number of albid coniform species are also present. In general, the conodonts are typical of the shallow-water biofacies and few have any biostratigraphical potential. C. loxoides has been recorded only a few times but seems to be restricted to the upper G. quadraplicatus Zone and the O. communis Zone (Kennedy, 1980; Repetski, 1982; Stouge, 1982). In North Greenland C. loxoides has a range which extends almost to the top of the O. communis Zone. Similarly, W. guyi has only been recorded previously from the upper part of the G. quadraplicatus Zone (Kurtz and Miller, GGU int. rept.) and the lower part of the O. communis Zone (Stouge, 1982); the species is present in the lower part of the O. communis Zone in the Cape Weber Formation, "A." staufferi ranges all the way through the G. quadraplicatus Zone in the El Paso Limestone but occurs only in the lower part of the O. communis Zone (Repetski, 1982). The presence of these three taxa in the lowermost part of the Wandel Valley Formation in both Peary Land (Fig. 5.5) and Kronprins Christian Land (Fig. 5.6) indicates an upper G. quadraplicatus - Lower O. communis Zone age.

O. communis only occurs in the Wandel Valley Formation in Kronprins Christian Land, where it occurs above 55 m up the formation, as does P. papiliosus. It is likely however that this first appearance is ecologically controlled since below this point the formation contains abundant scours with flat-pebble conglomerates and cross-lamination whereas above it scours are less frequent and there is no cross-

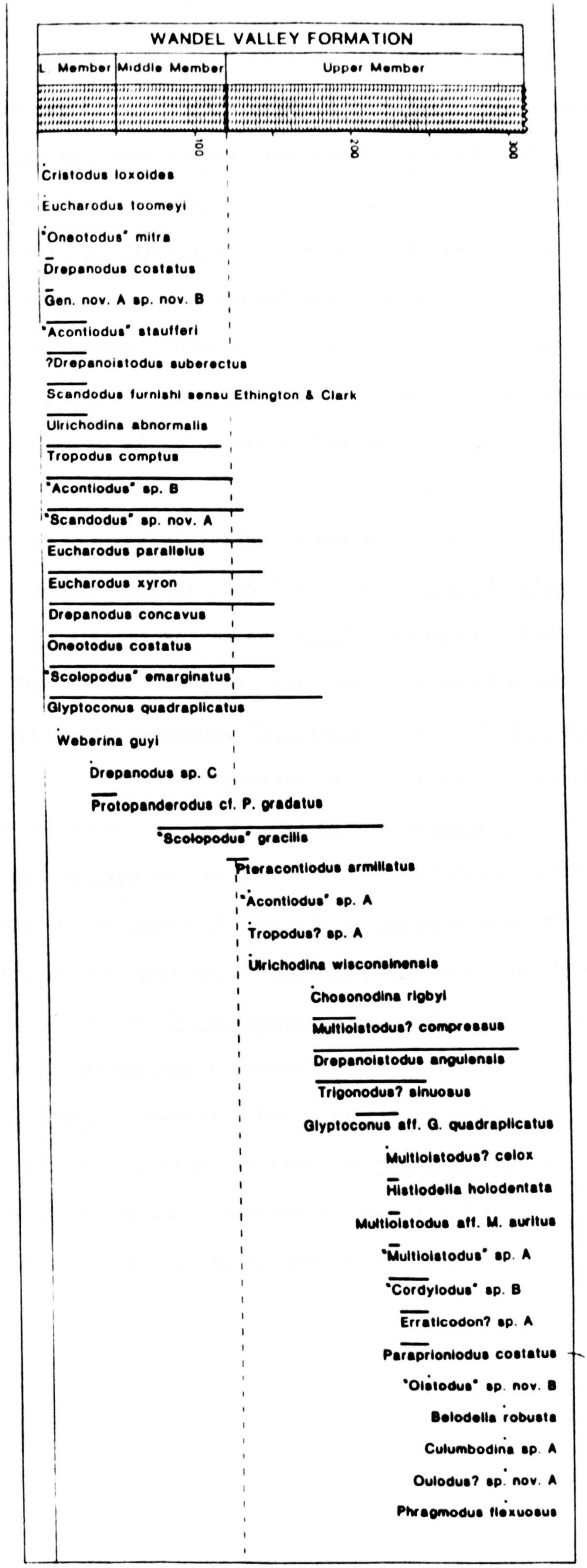


Fig. 5.5 Range chart of taxa in section JEM 790627-1, central Peary Land

lamination. Further evidence for this is that P. papiliosus is only found in the P. aranda Sub-Zone in the Ibex area (Ethington and Clark, 1982) although only two specimens were recorded. If further studies indicate that P. papiliosus does have a short range then its presence 55 m above the base of the Wandel Valley Formation is likely to indicate a lower O. communis Zone age for the base rather than upper G. quadraplicatus Zone. The conservative nature of the fauna prevents the identification of sub-zones in the upper Ibexian.

In the upper member of the Wandel Valley Formation faunal diversity is lower and sample yields smaller. In Peary Land, P. armillatus, "Acontiodus" sp. A., Tropodus? sp. A. and U. wisconsinensis occur 8 m above the base but above this level only the long-ranging taxa E. parallelus, E. xyron, O. costatus, "S." emarginatus and "S." gracilis are found (Fig. 5.5). The first diagnostic Whiterockian species are introduced 48 m up the member where C. rigbyi, M? compressus, D. angulensis and T? sinuosus are seen. Ethington and Clark (1982) found C. rigbyi only in the upper part of the H. sinuosa Zone although it does occur as low as the base of the H. altifrons Zone (Harris and Repetski, pers. comm.), as do D. angulensis and T? sinuosus. The first occurrence of M? compressus is somewhat lower, at the base of the M. flabellum/T. laevis Interval. The co-occurrence of these four species at 48 m indicates a position within the H. altifrons Zone but due to the low diversity and low abundance of faunas below this horizon, the underlying M. flabellum/T. laevis Interval is not identifiable.

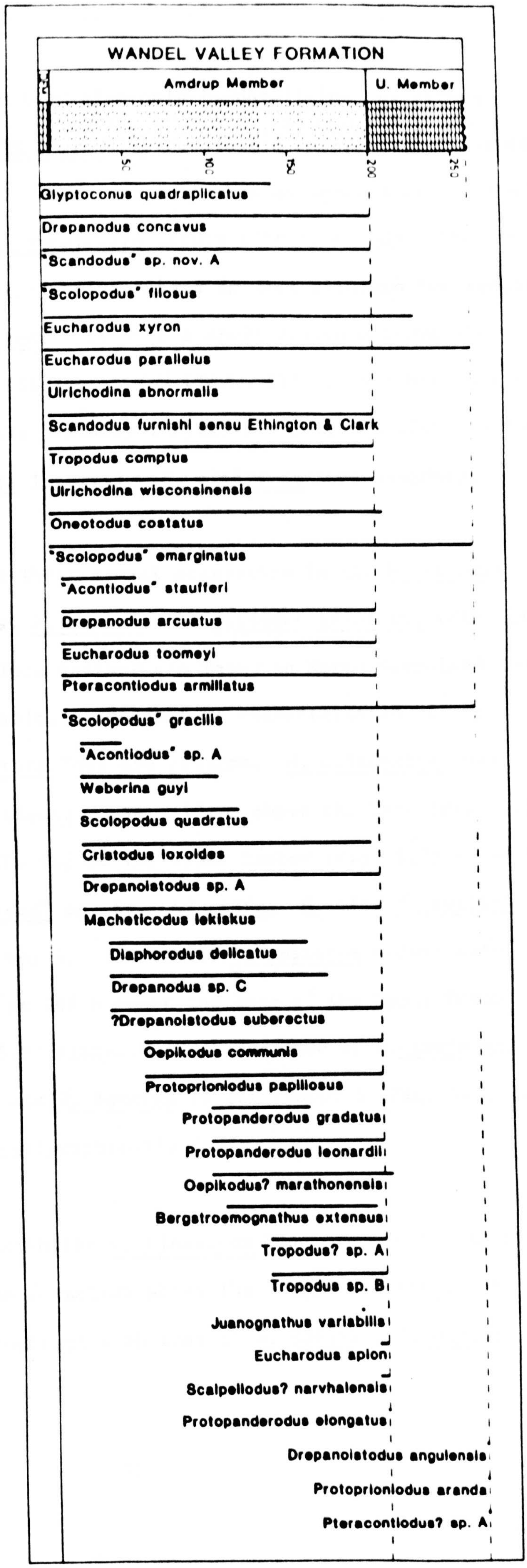


Fig. 5.6 Range chart of taxa in section JSP 800702-1, Kronprins Christian Land

In Kronprins Christian Land also only E. parallelus, E. xyron, "S." emarginatus and "S." gracilis continue a substantial distance into the Upper Member. The first Whiterockian species are seen 60 m up the member where D. angulensis occurs with P. aranda. The two species do not have overlapping ranges in Ibex although the lowest occurrence of D. angulensis is only a short distance above the highest of P. aranda (Ethington and Clark, 1982). The presence of both in the same sample probably indicates a position close to the M. flabellum/T. laevis Interval - H. altifrons Zone boundary.

Only two species have their lowest occurrence in the H. sinuosa Zone in the Ibex area, H. sinuosa and Oistodus cristatus (Ethington and Clark, 1982). Since neither are found in North Greenland the zone is not recognisable, although taxa characteristic of the overlying H. holodentata Zone are present. H. holodentata was recovered in two sections, at 94 - 101 m above the base (Fig. 5.5) and at 118 m below the top of the Upper Member (Fig. 5.7) where it occurs with "Cordylodus" sp. B., M? celox, M. aff. M. auritus and "Multioistodus" sp. A. The lowest P. costatus occurs with Erraticodon? sp. A. at 101 m above the base of the Upper Member in JEM 790627-1 (Fig. 5.5) although the occurrence of P. costatus, Erraticodon? sp. A. and W. fuscina in JEM 790701-1 (Fig. 5.7) is almost certainly stratigraphically lower.

Species associated with the P. flexuosus Zone are first seen 81 m below the top of the formation where the lowest occurrence of P. flexuosus is coincident with that of B. robusta, Culumbodina sp. A.,

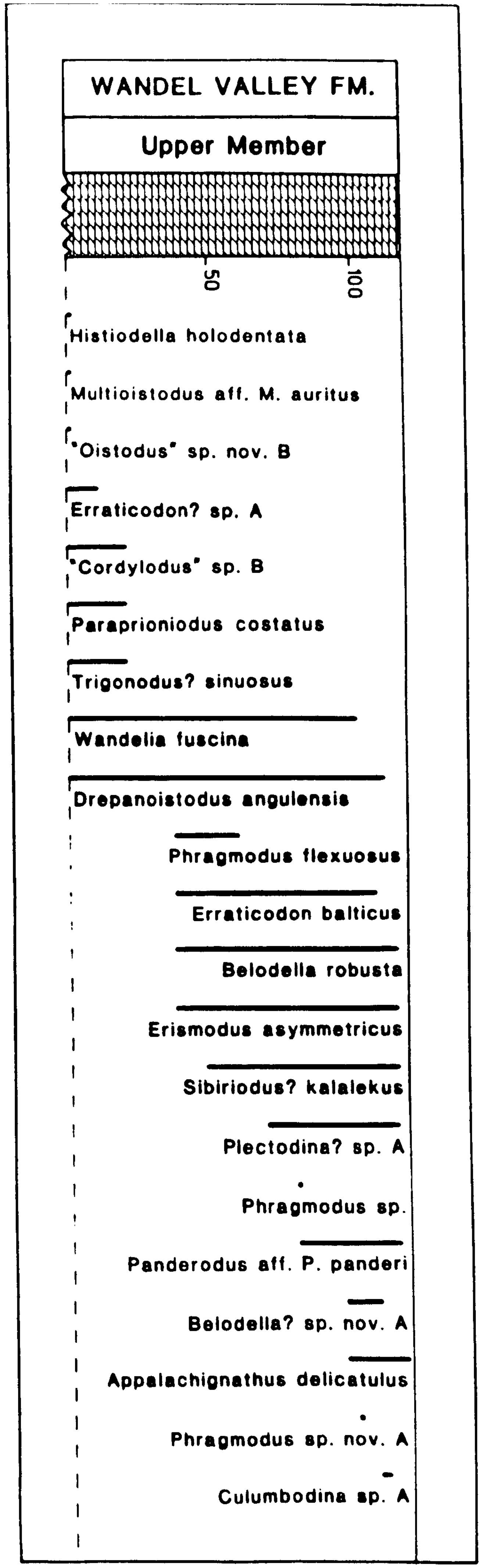


Fig. 5.7 Composite range chart of taxa in sections JEM 790627-2 and JEM 790701-1, central Peary Land

E. asymmetricus and E. balticus (Fig. 5.7). The only occurrence of P. flexuosus in JEM 790627-1 also coincides with that of Oulodus sp. nov. A. (Fig. 5.5).

The first occurrence of Phragmodus? sp. nov. A. rather then P. flexuosus is 17 m below the top of the Wandel Valley Formation in central Peary Land. Sweet (1984) considered the range-base of P. sp. nov. A. (P. flexuosus of Sweet) to be coincident with the base of the P. friendsvillensis Zone and, therefore, the Upper Whiterockian (Fig. 5.1).

The uppermost Wandel Valley Formation in western Peary Land, adjacent to Hans Tavsens Iskappe, is sparsely fossilferous, but the distribution of zones does not seem to be significantly different from that in Peary Land. P. costatus is found with W. fuscina, T? sinuosus and "Cordylodus" sp. B. from 115 m (base of section) to 80 m below the top of the formation (Fig. 5.8), the H. holodentata Zone thus extending up to at least 80 m below the top. S? kalalekus is found in samples from 17 to 1.5 m and is joined by A. delicatulus in the top sample. The presence of A. delicatulus even in low numbers, does, however, indicate that the age of the upper boundary is not significantly different from central Peary Land.

Sample coverage through the upper Wandel Valley Formation and the new, un-named formation permits only very approximate correlations with Børglum Elv. T? sinuosus and Wandelia? sp. nov. A. are present 30 m below the top of the Upper Member of the Wandel Valley Formation (Fig. 5.9), indicative of H. holodentata Zone since T? sinuosus is

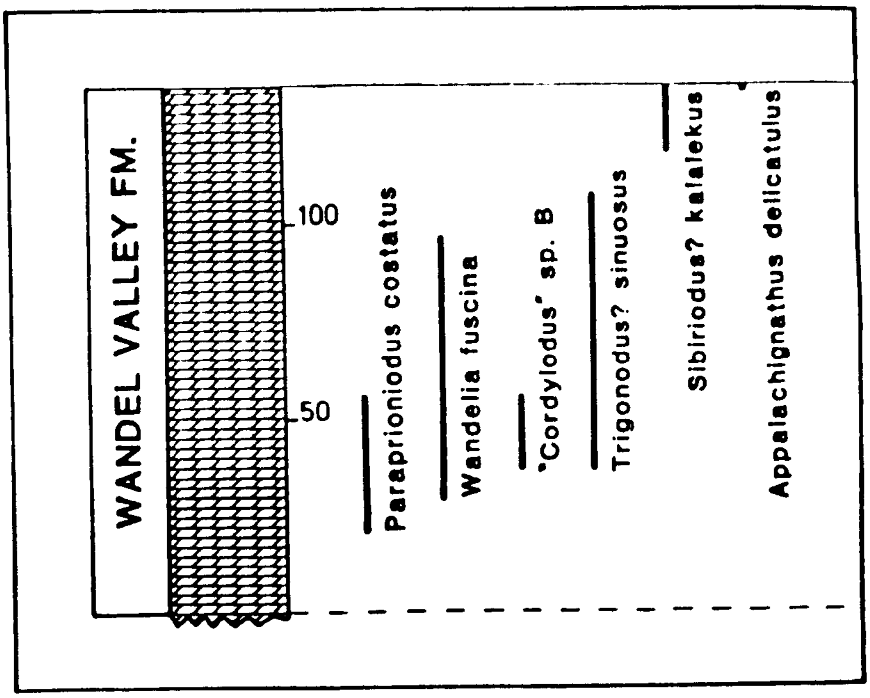


Fig. 5.8 Composite range chart of taxa in sections JSP 780711-1 and JSP 780711-2, western Peary Land

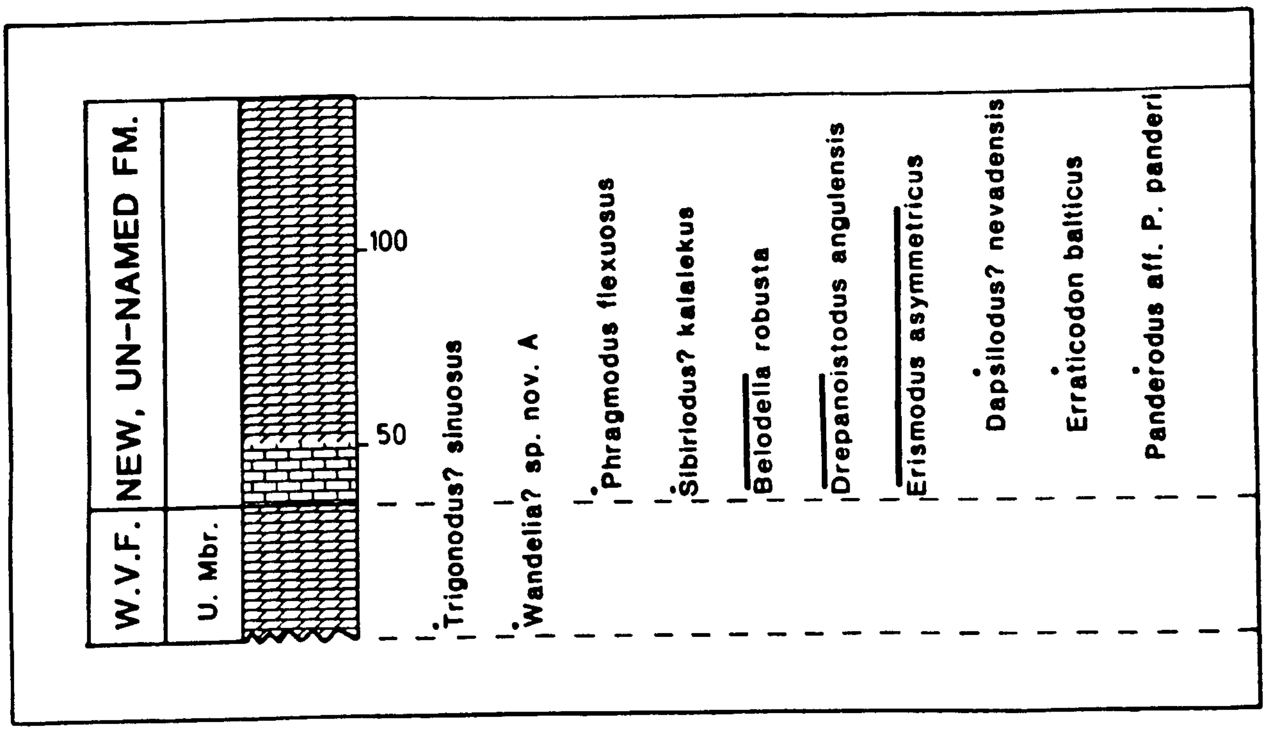


Fig. 5.9 Range chart of taxa in section JSP 800704-2, Kronprins Christian Land

not found in the P. flexuosus Zone. The next sample, 8 m up the new, un-named formation, contains P. flexuosus, S? kalalekus, B. robusta and E. asymmetricus, all of which are introduced in the base of the P. flexuosus Zone in Peary Land. Diagnostic taxa are not present higher up the formation, the only other sample (at 33 m) yielding D? nevadensis, E. balticus, P. aff. P. panderi, B. robusta and D. angulensis.

In summary, the base of the Wandel Valley Formation lies within the upper G. quadraplicatus or lower O. communis Zone, with slightly more evidence for the latter assignment. Species characteristic of the lowest biostratigraphical unit in the Whiterockian, the M. flabellum/T. laevis Interval, are not present but taxa characteristic of the H. altifrons Zone are first found 48 m and 60 m up the Upper Member in Peary Land and Kronprins Christian Land respectively. The Ibexian-Whiterockian boundary therefore lies at or just above the base of the Upper Member. The top of the Wandel Valley Formation in Peary Land contains species indicative of the P. friendsvillensis Zone. Evidence for the age of the new, un-named formation in Kronprins Christian Land is sparse but the presence of P. flexuosus 8 m above its base indicates that the formation is equivalent in age to the upper part of the Upper Member in Peary Land.

5.4. CORRELATION OF THE CAPE WEBER, NARWHALE SOUND AND HEIM BJERGE FORMATIONS WITH THE WANDEL VALLEY FORMATION

The lowest beds of the Wandel Valley Formation are equivalent in age to a level approximately 500 m up the Cape Weber Formation on Ella Ø

(Fig. 5.10). The base of the Upper Member approximates in age to the base of the Narwhale Sound Formation or a horizon slightly above the base, although on Albert Heim Bjerge the Ibexian-Whiterockian boundary occurs within the Cape Weber Formation (716 m above base).

The next widely identifiable zone is the *H. holodentata* Zone which occurs 94 m above the base of the Upper Member and extends to 81 m below the top in Peary Land; in East Greenland species characteristic of the zone are first seen at least 150 m below the top of the Narwhale Sound Formation and extend to 138 m in the Heim Bjerge Formation.

The youngest sediments of Ordovician age in East Greenland belong to the *P. anserinus* Zone, in the North Atlantic Province zonation of Bergström (1971) and correlate with the middle of the *P. sweeti* Zone (Fig. 5.1). These rocks are slightly younger than the top of the Wandel Valley Formation, which contain conodonts of the *P. friendsvillensis* Zone.

5.5. COMPARISON OF THE CONODONT BIOSTRATIGRAPHY WITH PREVIOUS MACROFAUNAL WORK

As outlined in Chapter 3, macrofossils are scarce in the succession studied, especially the Wandel Valley Formation, and there is consequently a limited amount of published data. Yochelsen and Peel (1975) described the gastropods *Ceratopea unguis* and *C. ankylosa* from the lower two members of the Wandel Valley Formation in Peary Land and considered them to be indicative of a late Ibexian age.

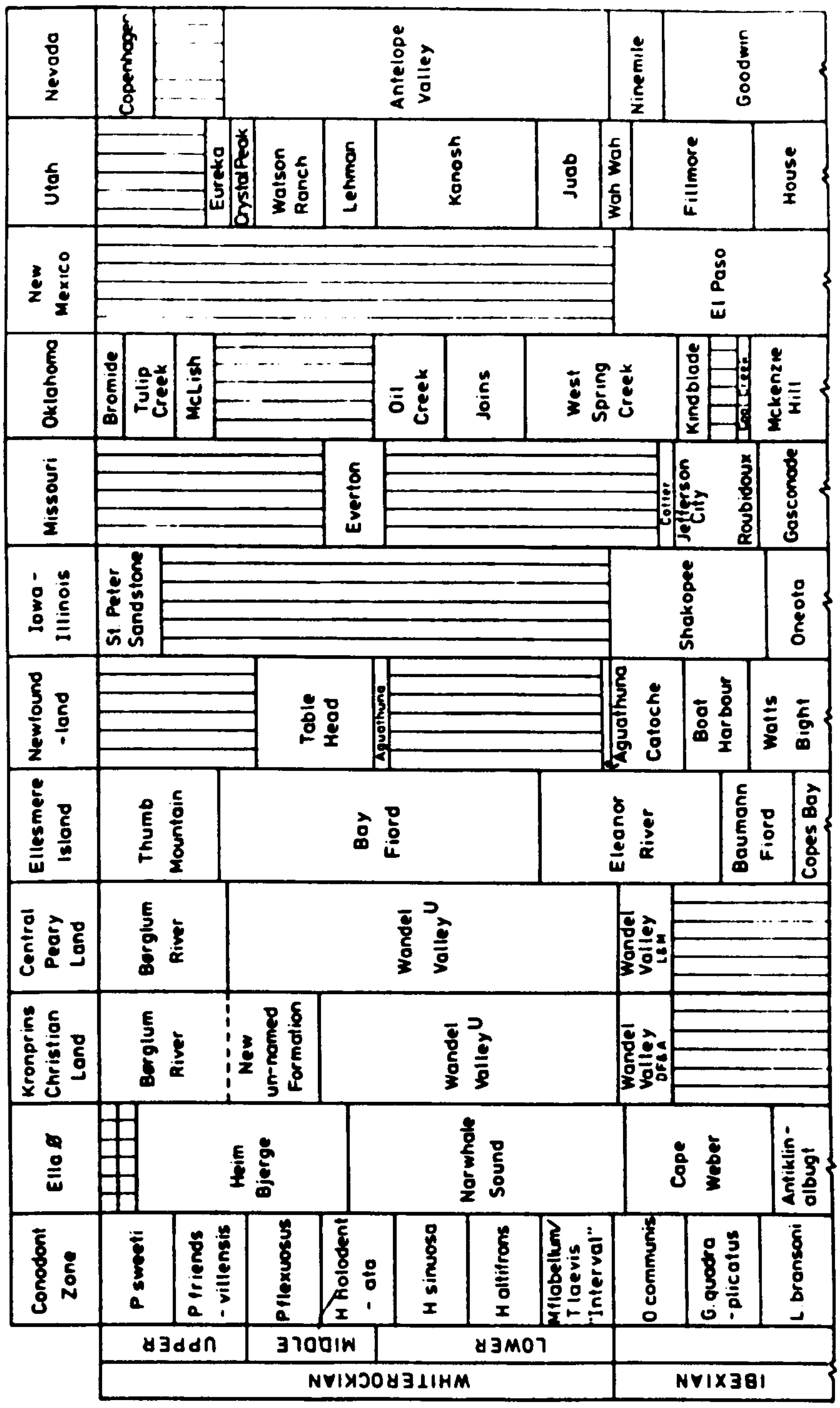


Fig. 5.10 Correlation chart of selected North American sections. Column 4 after Nowlan (1976), column 5 after Stouge (1982), columns 6, 7, 8 and 11 after Ross et al., (1982), column 9 after Repetski (1982), and column 10 after Ethington & Clark (1982)

C. billingsi has been found in both the Amdrup Member of the Wandel Valley Formation (Peel, 1980) and the Narwhale Sound Formation (Yochelson, 1964) and the two were thus considered to be coeval and of late Ibexian age by Peel (1980). The conodont evidence indicates that the Amdrup Member is of late Ibexian age but such an age for the Narwhale Sound Formation is only possible in the lower 95 m on Ella Ø. Further to the north the Ibexian-Whiterockian boundary occurs within the Cape Weber Formation.

The rare trilobite Ceratopeltis latilimbata has been described only from the Amdrup Member (Fortey and Peel, 1983) and the Cape Weber Formation (Poulsen 1937). A correlation of these two units based on the occurrence of C. latilimbata (Fortey and Peel, 1983) is in agreement with the conodont evidence. Cowie and Adams (1957) considered the fauna of the "Black Limestones" on Albert Heim Bjerge to be similar to those of Zone J in Utah. The "Black Limestones" occur between 550 and 600 m on Albert Heim Bjerge (Cowie and Adams, 1957) and unpublished GGU conodont collections support this correlation, the base of the P. aranda Sub-Zone being at 600 m. However, Cowie and Adams (1957) also considered the Heim Bjerge Formation to be of Trentonian age (= Mohawkian - Cincinnatian), whereas the conodont faunas indicate an age no younger than Upper Whiterockian.

5.6. CORRELATIONS WITH THE CANADIAN ARCTIC ISLANDS

The Lower and Middle Ordovician conodonts of Ellesmere and Devon Islands have been described by Barnes (1974), Nowlan (1976), Tipnis (1978), Mayr et al. (1980) and Landing and Barnes (1981) and correlation of the Ellesmere Island sequence with Greenland is shown in Fig. 5.10. The latter recorded L. bransoni Zone conodonts from the Cape Clay Formation of southern Devon Island and in the overlying Nadlo Point Formation, no hiatus being evident between the two (contra Barnes et al., 1980).

Nowlan (1976) recovered U? bassleri from the lower half of the Baumann Fiord Formation on northern Devon and Ellesmere Islands. G. quadraplicatus was only present in the upper quarter of the formation, but the presence of M. dianae, a species with a restricted range in the middle G. quadraplicatus Zone, indicates that the L. bransoni Zone - G. quadraplicatus Zone boundary lies close to the middle of the Baumann Fiord Formation (Fig. 5.10). The lowest O. communis occurs in the middle of Member 2 of the overlying Eleanor River Formation where it coincides with the lowest occurrences of M. lekiskus. The base of the ?R. andinus Sub-Zone is at the base of Member 3 and J. gananda is joined by O. multicorrugatus in mid-member. The overlying Bay Fiord Formation contains T? sinuosus, Coleodus, P. costatus and W. fuscina close to the base. These taxa are indicative of an upper H. sinuosa or H. holodentata Zone age and imply that a disconformity may be present at the base of the formation. P. flexuosus occurs just below mid-height in the formation and A. delicatulus in the upper quarter. The Wandel Valley Formation below the Upper Member is thus equivalent in age to Member 3, and probably most of Member 2, of the Eleanor River Formation (Fig. 5.10). The Bay Fiord Formation correlates with the Upper Member in Peary Land and the Upper Member and new, un-named formation in Kronprins Christian Land - a correlation also made by Peel and Christie (1982) and Peel (in press) on lithological criteria.

A carbonate unit which occurs between the Hazen and Imina Formations of the Hazen Trough on Ellesmere Island has yielded Pygodus and Periodon aculeatus (Tipnis, 1978). The presence of Pygodus indicates an uppermost Middle to Upper Whiterockian age (Sweet, 1984) (Fig. 5.1) and, hence, a correlation with the top of the Wandel Valley Formation and the upper part of the Heim Bjerge Formation.

Further to the south, a well drilled on Somerset Island penetrated strata as low as the upper Cass Fjord Formation (Mayr et al., 1980). The oldest conodonts recovered were from the overlying Cape Clay Formation and of the L. bransoni Zone. A succeeding, un-named unit yielded G. quadraplicatus Zone faunas (op. cit). Miall and Kerr (1980) also listed conodont collections from Somerset Island and the Boothia Peninsula. The Turner Cliff Formation is of early Ibexian age and a sample from the overlying Ship Point Formation yielded E. parallelus, G. quadraplicatus, D. concavus and Trigonodus akpatokensis, indicative of a probable O. communis Zone age.

Barnes (1974, 1977) examined the conodonts of the Ship Point and Bad Cache Rapids Formations. The latter is Mohawkian in age but the lower part of the Ship Point Formation in the Foxe Basin contains upper Ibexian faunas (Barnes, 1974). The youngest samples from the formation on the Melville Peninsula, contain P. flexuosus or P. sp. nov. A. (Barnes, 1977) indicative of the P. flexuosus Zone - P. friendsvillensis Zone. The Ship Point Formation thus has upper and lower boundaries closely similar in age to those of the Wandel Valley Formation.

5.7. CORRELATIONS WITH CANADA AND THE U.S.A.

Stouge (1982, 1983) has documented the conodont faunas of the St. George Group and the Table Head Formation of Newfoundland. The lowest occurrence of G. quadraplicatus is at the top of the Boat Harbour Formation, but M. dianae is present above the lower one-fifth of the formation and the base of the G. quadraplicatus Zone is likely to approximate to the Watts Bight - Boat Harbour Formation boundary or be in the upper Watts Bight Formation (Fig. 5.10). The base of the O. communis Zone is at the base of the Catoche Formation and B. extensus is present within the Laignet Point Member. The lowest Whiterockian faunas are seen in the Aguathuna Formation and contain P. costatus and T? sinuosus indicative of the upper H. sinuosa - H. holodentata Zone, a substantial disconformity thus being present at the base of the Aguathuna Formation. This is in agreement with macrofaunal evidence (Fortey, 1979) but suggests that the dolomites placed in the Ibexian by Fortey (1979) should be assigned to the Whiterockian. The Catoche Formation can be correlated with the Lower and Middle Members of the Wandel Valley Formation and the Aguathuna and Table Head Formation with the Upper Member (Fig. 5.10).

The Shakopee Formation of Illinois (Furnish, 1938) and Wisconsin (Grether and Clark, 1980), the Jefferson City Formation of Missouri (Branson and Mehl, 1933; Kennedy, 1980) and the Kindblade Formation of Oklahoma and Arkansas (Brand, 1976; Kennedy, 1980) all contain shallow water faunas closely similar to the lower part of the Wandel Valley Formation. It is likely that all three formations straddle the G. quadraplicatus - O. communis Zone boundary (Ross et al.,

1982) although the absence of O. communis in the Shakopee Formation may indicate a position entirely within the G. quadraplicatus Zone (Kennedy, 1980). None of the formations is known to extend into the Whiterockian.

In Oklahoma and Arkansas, the base of the Whiterockian lies within the West Spring Creek Formation (Potter, 1975). The overlying Joins Formation has conodonts of H. altifrons Zone through to H. sinuosa Zone (Mound, 1965b). The latter zone continues through the Oil Creek Formation which is bounded at the top by a disconformity (Sweet and Bergström, 1976; Sweet, 1984). The succeeding McLish, Tulip Creek and Bromide Formations are of uppermost Whiterockian - Mohawkian age, the boundary falling within the Bromide Formation (Sweet, 1984) (Fig. 5.10).

The conodonts of the El Paso Limestone have been comprehensively described by Repetski (1982). The lowest part of the sequence belongs to the L. bransoni Zone. Examination of Repetski's collections show that the first hyaline G. quadraplicatus occurs at 79 m. The lowest O. communis is at 256 m and the bases of the ?R andinus Sub-Zone and P. aranda Sub-Zone can be recognised at 360 m and 396 m respectively. The top of the formation is at 410 m and no Whiterockian is present. The El Paso Limestone is similar in age to the Cape Weber Formation on Ella Ø (Fig. 5.10).

The zonation of the Ibex sequence by Ethington and Clark (1982) has already been discussed and the correlation of these formations with those of Greenland is shown in Fig. 5.10. The westernmost sequences with well studied conodonts are those of Antelope Valley, Nevada and the Nevada Test Site. There, the base of the G. quadraplicatus Zone lies within the lower part of the Goodwin Limestone and that of the O. communis Zone within the upper part (Ethington, 1979; Ross et al., 1982) (Fig. 5.10). The Antelope Valley Limestone has Whiterockian conodonts ranging from the base of the series through to the P. friendsvillensis Zone (Harris et al., 1979; Sweet, 1984). The top of the formation is bounded by a disconformity and the lower part of the succeeding Copenhagen Formation contains P. sweeti Zone conodonts (Harris et al., 1979; Sweet, 1984).

5.8. CORRELATIONS WITH PARTS OF THE MIDCONTINENT PROVINCE OUTSIDE OF NORTH AMERICA

Ny Friesland, Spitsbergen, has an Ibexian carbonate succession very similar to that of East Greenland (Swett, 1982). The Spora Member of the Kirtonryggen Formation contains shelly fossils of Ross - Hintze Zones B - D (Fortey and Bruton, 1973) and the upper part of the member is therefore likely to correlate with the base of the Cape Weber Formation (Fig. 5.1) on Ella Ø and the upper Antiklinalbugt Formation on Albert Heim Bjerge. The overlying Basissletta Member is poorly fossilferous but is of probable mid-Ibexian age (Fortey and Bruton, 1973). The uppermost member of the Kirtonryggen Formation, the Nordporten Member, contains probable G. quadraplicatus Zone conodonts in the lower part (Fortey and Barnes, 1977) but faunas from the middle and upper parts contain Tropodus and Bergstroemognathus and are generally similar to those of O. evae Zone age (Fig. 5.1) described by Serpagli (1974) from Argentina. The lower part of the overlying Olenidsletta Member (Valhallfonna Formation) also contains O. communis Zone faunas but the succeeding Profilbekken Member marks the incoming of a deeper-water Periodon dominated fauna at the base of the Whiterockian. This stratigraphic interval was termed the Valhallan Stage by Fortey (1979) who considered it to be absent over most of the Midcontinent Province. Low diversity and low abundance conodont faunas are, however, now known to be present in most areas (Harris and Repetski, pers. comm.).

Swett and Smit (1972a) also considered the carbonates of the Durness Group to be close correlatives of the East Greenland Ordovician. The conodonts of the Durine Formation have been described briefly by Higgins (1967) and those of the Croisaphuil Formation listed by Higgins (1971). Reconnaissance reference collections were made for this study and the unpublished data is used here. The middle Balnakiel Formation contains Macerodus dianae, indicating an Acodus deltatus Sub-Zone age. Samples from the lower Croisaphuil Formation contain O. costatus and T. comptus which also have the bases of their range in the G. quadraplicatus Zone. However, a sample from the middle of the formation contains B. extensus, W. guyi and T. comptus, the first of which is known only from the O. communis Zone. A sample from the Durine Formation contains O. multicorrugatus, S. emarginatus, E. parallelus, "S." gracilis, C. rigbyi and a species of Wandelia; C. rigbyi does not occur in strata older than the H. altifrons Zone (Harris and Repetski, pers. comm.). The Balnakiel Formation thus correlates with the lower part of the Cape Weber Formation on Ella Ø. The lower part of

The Croisaphuil Formation is equivalent to the upper part of the Cape Weber Formation and at least the top half of the Croisaphuil Formation correlates with the lower two members of the Wandel Valley Formation. The Durine Formation is equivalent in age to the lower part of the Narwhale Sound Formation and the lower part of the Upper Member of the Wandel Valley Formation.

Bergström (1979) described a Whiterockian fauna from the Hølonda region of Norway. The presence of B. robusta enables a correlation with the lower part of the Heim Bjerge Formation and the uppermost part of the Upper Member of the Wandel Valley Formation.

CHAPTER 6

CONODONT GEOTHERMOMETRY

6.1. INTRODUCTION

It has long been recognised that conodonts change colour from amber to grey or black in rocks adjacent to igneous intrusions (Ellison, 1944; Sweet and Bergström, 1966), but it was not until relatively recently that Epstein et al. (1977) attempted to find the cause of such changes and quantify the process.

Conodonts are composed of a carbonate apatite, approximating to francolite, which has a bulk formula of

$$Ca_5\ Na_{0.14}\ (PO_4)_{3.01}\ (CO_3)_{0.16}\ F_{0.73}\ (H_2))_{0.85}$$

(Pietzner et al., 1968). When heated in a sealed tube, conodonts give off water and darken to grey (Ellison, 1944), a feature attributed by Lindström (1964) to a carbon-fixing process. Organic matter has been identified in conodonts (Pietzner et al., 1968) and fixation of this does appear to be one of the principal causes of the change in colour (Epstein et al., 1977).

In order to quantify the change in colour, Epstein et al. (1977) took unaltered conodonts and subjected them to heating, in a furnace, at 300 - 600°C for 10 - 50 days. The experiment indicated that colour alteration seen in field samples could be reproduced in the laboratory and that the alteration itself is progressive, cumulative, irreversible and time and temperature dependent. To determine whether the process was also pressure dependent, Epstein _et al._ (1977) heated unaltered conodonts in a bomb at 1 Kbar using argon and methane as pressure media. Heating under such conditions without water produced the same results as at atmospheric pressure but heating at 1 Kb with water retarded carbonisation and temperature assessment was consequently too low. In practice, however, such sealed systems would be rare and only expected to occur in overpressured rocks.

An Arrhenius plot for the heating was constructed by Epstein _et al._, who decided that five colour intervals could be readily discriminated, although a further three intervals were subsequently added to the top of the range to account for high temperature alterations seen in field collections. These intervals were numbered and termed colour alteration indices (CAI).

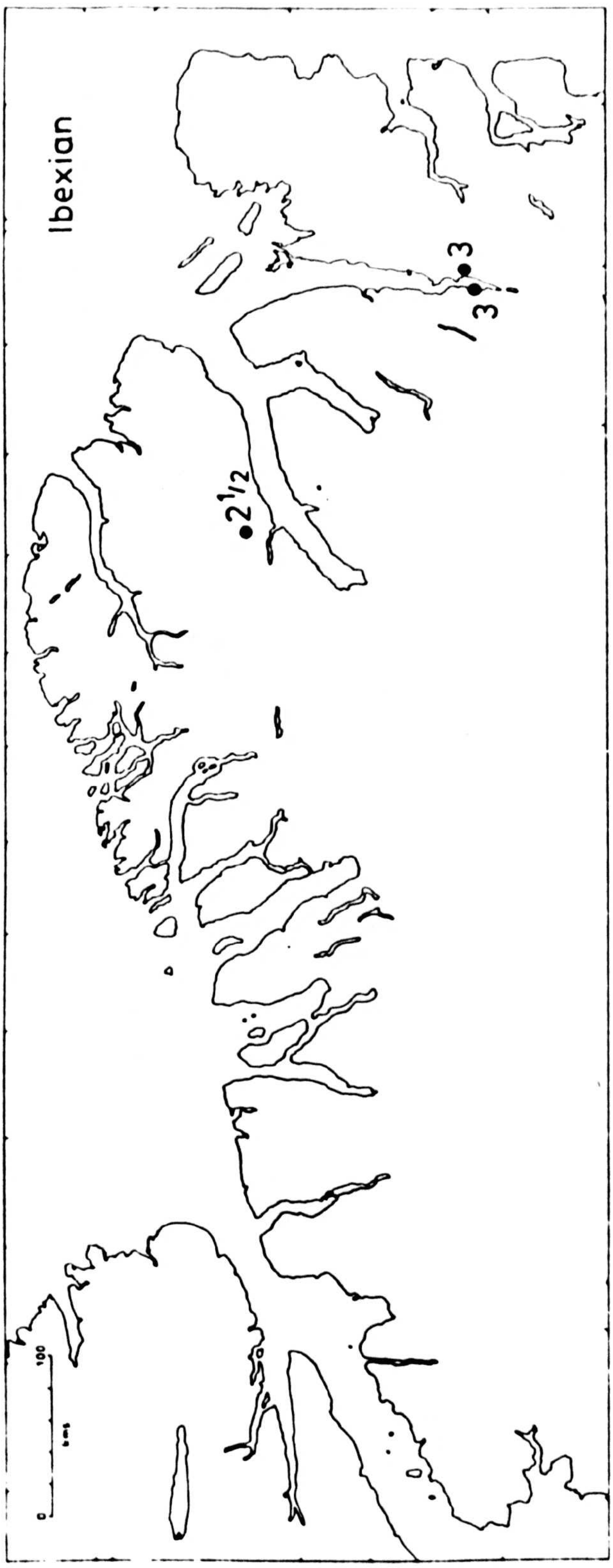
6.2. DETERMINATION OF CAI

The well-laminated basal part of conodont elements contains the largest proportion of organic matter (Epstein _et al._, 1977) and CAI determinations are hence made between the basal cavity and the margin of the element. Cusps and denticles which contain white matter are unsuitable since they remain essentially unchanged up to CAI 4. The colour of conodonts may also be affected by factors other than temperature, such as leaching, superficial staining or infilling of the basal cavity with mineral or organic material. Staining may result from certain processing procedures; if Merrill's Solution (Merrill, 1980) is used to oxidise pyrite in the sample, the conodonts will be stained dark brown. Some variations in colour may also be attributed to original differences in element colour in different species, and structure, robustness and maturity of the individual elements certainly have an affect.

When determining the CAI in my collections, comparisons were made between the elements in the sample, a CAI colour chart (Epstein et al., 1977) and a standard set of conodont specimens showing different CAI supplied by Dr A Harris. In order to minimise the effects of colour variation several samples were studied from each locality and the same species or group of species used at each stratigraphical horizon. The criteria for choosing these species were that they should be relatively abundant and common to all of the sections. Glyptoconus quadraplicatus and Eucharodus parallelus were used in the Ibexian; Paraprioniodus costatus in the middle Whiterockian; Appalachignathus delicatulus and Panderodus sp. in the upper Whiterockian; Panderodus spp. in the Cincinnatian. The use of different taxa at different stratigraphical horizons is unavoidable but it does mean that samples from the different levels are not absolutely comparable, although the discrepancies are likely to be small.

6.3. CAI GEOTHERMOMETRY IN GREENLAND

The relatively small number of data points at each horizon (Fig. 6.1-4) broadly show an increase in CAI from east to west and from south to north. Since the thickness of sediment separating each of these horizons is never more than a few hundred metres, and consequently the CAI do not change from horizon to horizon, the data were combined



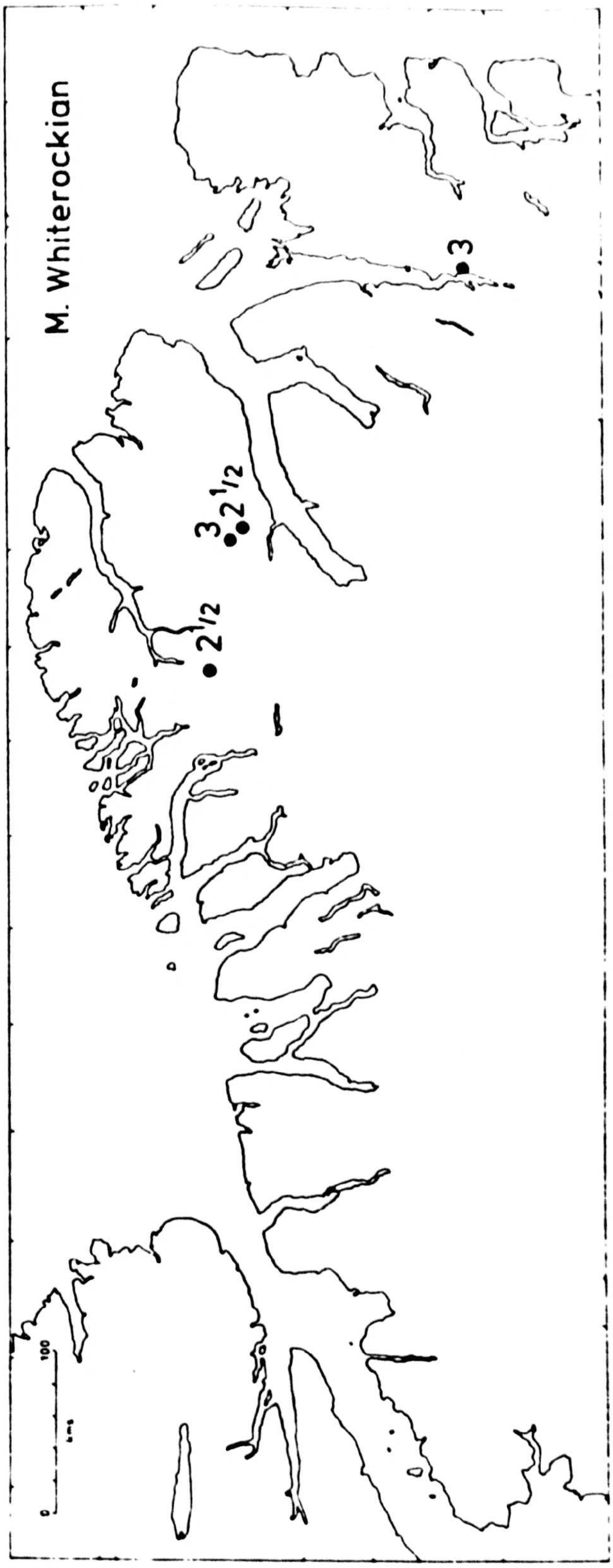
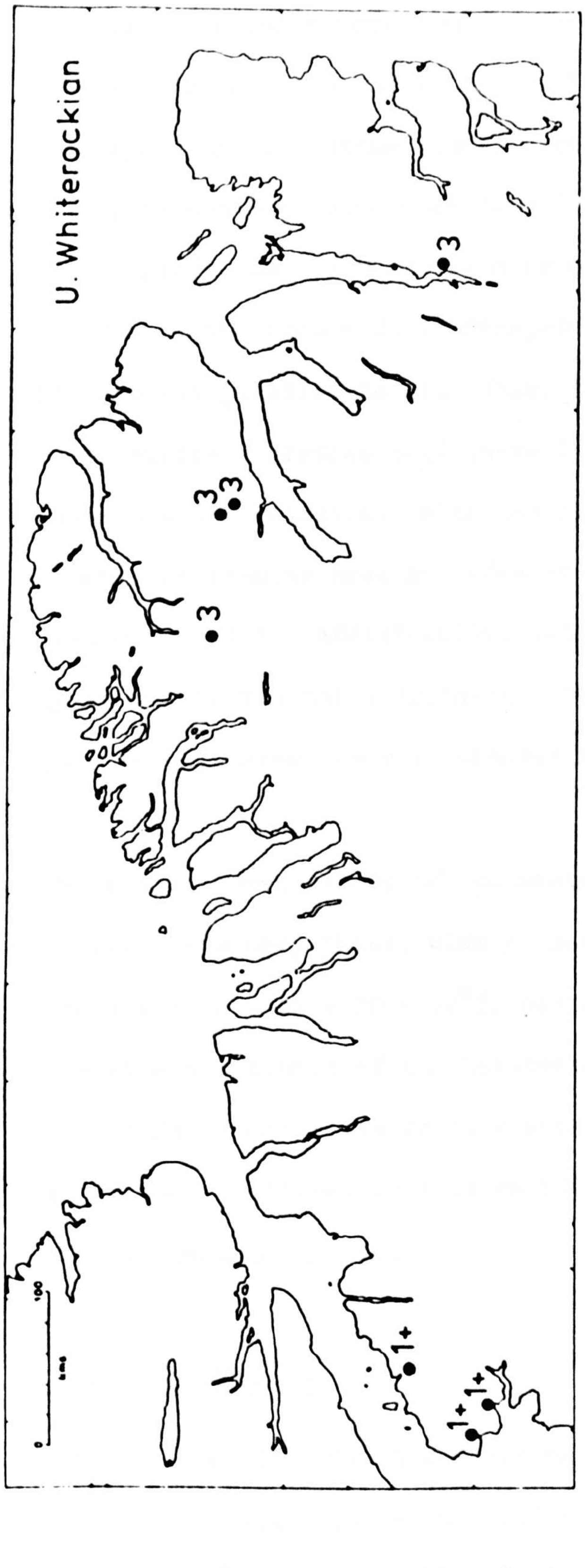


Fig. 6.1 Conodont alteration indices for the Ibexian of North Greenland

Fig. 6.2 Conodont alteration indices for the Middle Whiterockian of North Greenland



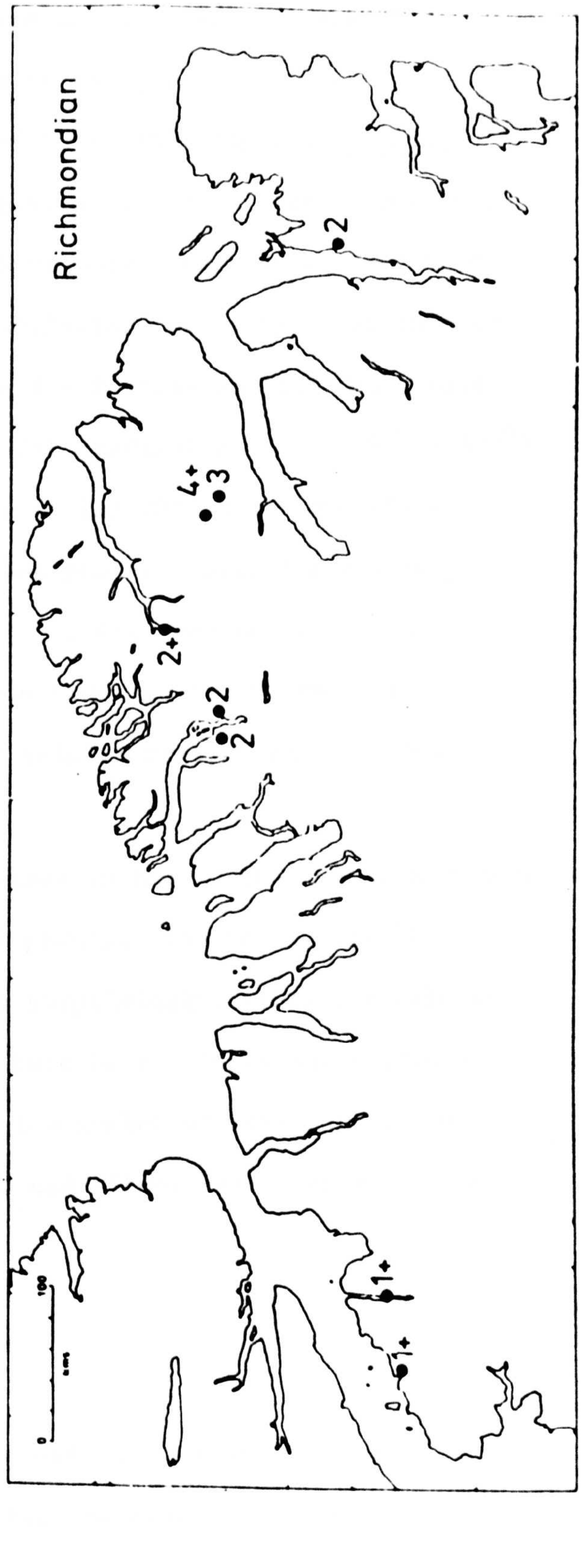


Fig. 6.3 Conodont alteration indices for the Upper Whiterockian of North Greenland

Fig. 6.4 Conodont alteration indices for the Richmondian of North Greenland

and plotted with Silurian data points from North Greenland (Aldridge, Armstrong and Smith, 1983, GGU int. rept.). The combined data set was contoured and a more complete picture can be seen. In western North Greenland, the CAI increases from 1+ to 3, south to north, corresponding to minimum temperatures of 50 - 110^{o}C (Epstein et al., 1977); in eastern North Greenland CAI grades from 2 to 5 (60 - 300+^{o}C). The isograds run E - W across most of North Greenland but as they near the Caledonian fold belt in Kronprins Christian Land they swing through 90^{o} and run parallel to it. Thus, in a W - E traverse from Peary Land to Kronprins Christian Land there is a CAI gradient of 2 - 4 (60^{o} - 300^{o}). Anomalous CAI values are obtained in Kronprins Christian Land where Ordovician samples have an index of 3 but younger, Silurian samples have a CAI of 4. Additionally, values of 2 are recorded in areas lying within the CAI 4 isotherm. Sample coverage is, however, rather poor in this area and more samples may help to resolve the problem.

The sample coverage for CAI determinations in East Greenland is extremely sparse, with only three, widely spaced points. The CAI is low (1½ - 2, minimum temperature 50 - 60^{o}), perhaps surprisingly, since the samples are from the centre of the Caledonian fold belt. It is not possible to firmly identify trends from such a low number of data points, but there is an increase from 1½ on Ella Ø and Albert Heim Bjerge to 2 on C.H. Ostenfeld Nunatak.

6.4. DISCUSSION

The immediately evident feature on the overall CAI map of North Greenland (Fig. 6.5) is that all the isograd trends are regional, with no evidence of hotspots such as those documented by Legall et al.

Fig. 6.5 Contoured colour alteration indices for a composite Ibexian-Llandovery data set

(1981) in eastern Canada. As the CAI values in East Greenland are so low, it can be assumed that high heat flow associated with the Caledonian Orogeny was not responsible for the high values in North Greenland, especially since Peary Land is some 200 km west of the orogen.

Sediments of the Wandel Sea Basin in Kronprins Christian Land, Peary Land and Johannes v. Jensen Land were also affected by strong folding and low-grade metamorphism in early Permian to late Palaeocene times, the main thermal event occurring in the post-Coniacian to Palaeocene, with a minor post-Palaeocene event (Håkansson et al., 1981). The resulting low grade metamorphism is, however, localised and palynomorphs are still recovered from many parts of the sequence (Piasecki in Håkansson et al., 1981). This irregular, localised heating cannot be invoked to explain the regional trends seen in North Greenland but might contribute to some of the high CAI in north Peary Land and may account for the anomolous CAI values recorded in Kronprins Christian Land. Thus, Mesozoic orogenic activity may be of local significance but is unlikely to account for regional trends, a conclusion supported by the presence of pale amber Permian conodonts in East Greenland (Sweet, 1976).

Epstein et al. (1977), Harris (1979) and Legall et al. (1981) have shown that, rather than direct orogenic activity, it is the depth and duration of burial which is the most significant factor in accounting for CAI isograds. In this respect, the trend of the isotherms, parallel to the margin of the Hazen Trough, may reflect the overburden of trough sediments. Approximate depths of burial, and hence overburden, can be calculated using a generalised geothermal gradient but Armstrong (1983) has attempted a more detailed approach to calculating depths of burial. Using the standard heat flow equations of Richardson and Oxburgh (1978) it was possible, knowing the temperature (CAI), estimated surface heat flow, overburden composition and overburden thermal conductivities, to calculate the depth of burial. The overburden composition for the Wandel Sea Basin was taken from Håkansson <u>et al.</u> (1981) and, since the thermal conductivities of Greenland sediments are unknown, the conductivity values of Carboniferous limestones, sandstones and mudstones were used. Thus, to cite an example, Armstrong (1983) calculated that the Silurian of Peary Land, with a 50% sandstone, 30% mudstone, 20% limestone overburden, would have had to be buried to depths of 4.0 - 7.4 km to account for a CAI of 3 and 7.0 - 10.9 km for CAI4. It was concluded that simple burial could account for even the highest temperatures attained (CAI5, Fig. 6.5) on the North Greenland platform. The technique used by Armstrong (1983) also allows estimates to be made of the amount of overburden removed, up to 1.5 km, in Washington Land.

The reason for the 90° swing in the isotherms is open to debate and could be due to a combination of factors. The isotherms essentially follow the margin of the trough and may reflect a continuation of the trough parallel to the east coast of North Greenland although there is no direct evidence of such a continuation. Alternatively, the isotherms may swing round to the trend of the Caledonides due to burial under a nappe stack in Kronprins Christian Land (Hurst and McKerrow, 1981 a & b; Hurst *et al.*, 1983), the nappes additionally being possible contributors to the CAI anomalies and irregularities in this area. Increased heat flow in the Caledonides up until the present, as documented by Richardson and Oxburgh (1978), could then increase the temperature for any given depth of burial and accentuate the swing in the isotherms. Subsequent burial by up to 7 km of sediments of the Wandel Sea Basin (Håkansson et al., 1981) and localised low-grade metamorphism would overprint these earlier events and might also account for some of the CAI anomalies seen in Kronprins Christian Land.

CHAPTER 7

FUSED CLUSTERS: IMPLICATIONS FOR CONODONT PALAEOBIOLOGY

7.1. INTRODUCTION

Natural assemblages of conodont elements, in which complete or partial apparatuses are preserved in a life or near-life position, can be divided into two types; bedding plane assemblages and fused clusters. The former usually yield the most palaeobiological information but are rarer and have not yet been recorded from the Ordovician. Fused clusters are normally obtained from acid residues and are usually only partial apparatuses. Their mode of preservation has been attributed both to pathological fusion (Rexroad and Nicoll, 1964; Barnes, 1967; Pollock, 1969) and to early diagenesis with silica and/or phosphate cementing the elements before they disperse due to decay (Landing, 1977; Repetski, 1980).

Clusters are of use in two respects. Firstly, they provide a means of testing current apparatus reconstructions and functional models. Secondly, the data they provide constraints for future apparatus models and reconstructions. Clusters are often the only reliable means of assessing relative numbers and positions of elements within an apparatus.

The majority of fused clusters described from the Lower Palaeozoic are of the Upper Cambrian to Lower Ordovician protoconodont "Prooneotodus" tenuis (Müller, 1959) and these are now known from Russia (Abaimova, 1980) Poland (Szaniawski, 1980, 1982), Sweden

(Müller and Andres, 1976), Britain (Miller and Rushton, 1973), the United States (Landing, 1977; Repetski, 1980) and Canada (Tipnis and Chatterton, 1979). There are relatively few descriptions of Lower Palaeozoic euconodont clusters, but fused elements of Silurian ramiform apparatuses have been described by Rexroad and Nicoll (1964) and Pollock (1969). Descriptions of fused clusters of coniform euconodonts now cover Belodina (Barnes, 1967; Nowlan, 1979), Besselodus (Aldridge, 1982) and Panderodus (Pollock, 1969), all of Upper Ordovician or Silurian age. The only previous record of Lower or Middle Ordovician euconodont clusters is that of Repetski (1980) who listed the recovery of Cordylodus and Oneotodus from the Ibexian of Nevada.

Landing (1977) in his study of "Prooneotodus" tenuis clusters, developed a terminology for describing the orientation of their constituent elements. These terms can also be applied to coniform euconodont clusters; parallel-opposed clusters have individual elements or groups opposed with cusp bases and tips in juxtaposition and their posterior margins adjacent (Fig. 7.1a), parallel-reversed clusters have the cusp tips of one group in contact with the bases of the opposing group (Fig. 7.1b).

7.2. CLUSTERS OF "SCOLOPODUS" GRACILIS ETHINGTON AND CLARK, 1964

Three fused clusters of S. gracilis elements were recovered from the Cape Weber Formation on Ella Ø and Albert Heim Bjerge. The smallest cluster (Pl.20, Fig. 2 ; GGU 270024) contains three s elements in a parallel-reversed arrangement with the tip and posterior margin of one element fused to the base and anterior margin of its

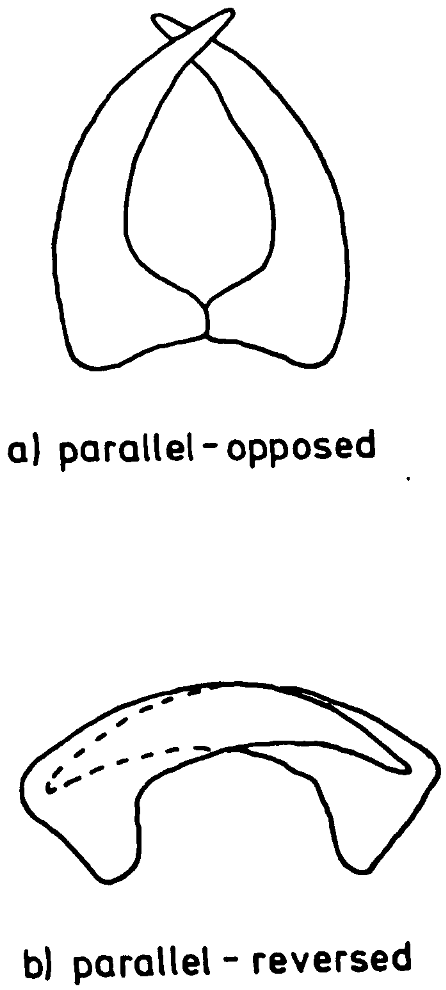


Fig. 7.1 Terminology for fused clusters

opposing element. The third element is fused to the side of this pair but is twisted so that the cusp tip lies obliquely across the other elements of similar orientation. The opposing element fractured during mounting for SEM photography, leaving only its cusp tip in place.

The second cluster (Pl. 20, Figs 3, 4 ; GGU 239753) comprises five s elements and a t element. Four of the s elements occur as a nested set with the sub-triangular anterior margin located in the v-shaped posterior groove of the adjacent element. The size of the elements decreases towards the posterior; the posteriormost element has a narrow, rather than v-shaped, posterior groove and is slightly offset from the anterior-posterior plane. The largest, most anterior element became detached from the cluster during handling. Elements of the type with the v-shaped posterior groove were referred to Scolopodus triangularis by Ethington and Clark (1964) and those with a narrow groove to S. gracilis.

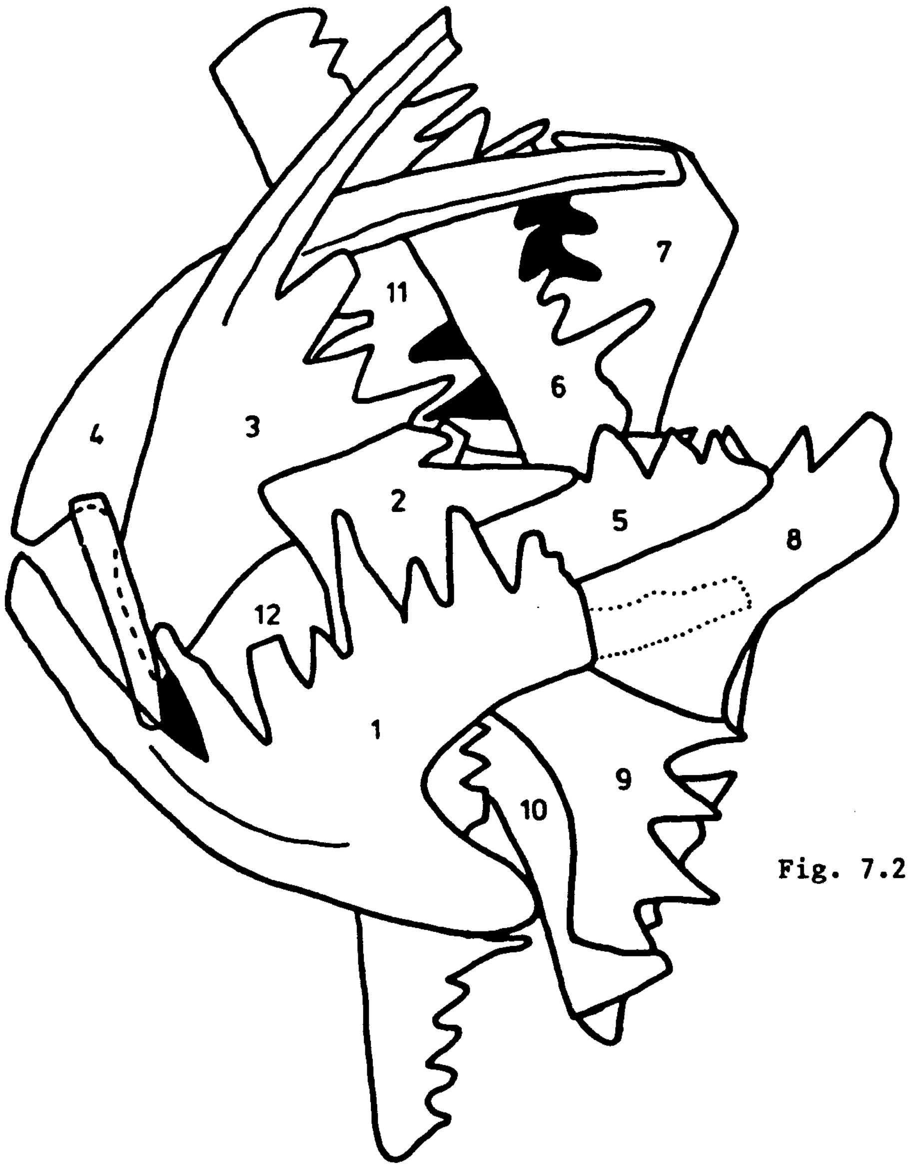
The posterior face of a t element is fused to the side of the four s elements. The edge of the widest postero-lateral face is sub-parallel to the curvature of the nested s elements and the margin of the narrower face hence runs obliquely across their lateral faces. The t element is of a similar morphology to specimens referred by other authors to Protopanderodus asymmetricus Barnes and Poplawski, 1973; taxonomic implications of this association are discussed in Chapter 4.

A third cluster (Pl. 20, Fig. 1 ; GGU 239743) consists of at least nine elements but is poorly preserved and somewhat disorganised. All of the identifiable elements are s elements and they appear to occur in nested pairs with some degree of parallel-reversed orientation preserved. It is possible that the rather disorganised preservation may be due to a faecal origin although decay of soft parts prior to fusion of the elements is an alternative explanation.

7.3. CLUSTERS OF *OEPIKODUS COMMUNIS* (ETHINGTON AND CLARK, 1964)

One of the clusters of *O. communis* elements is the largest cluster so far recovered from Greenland (Pl. 19, Figs 1 - 3, Fig. 7.2; GGU 239755), comprising at least twelve elements, all in the same plane. In the centre of the cluster are two P elements, distinguished by the posteriorly inclined denticles and triangular basal cavity outline (elements 8 and 9 on Fig. 7.2). The posterior processes are orientated at 90° with respect to each other and both elements are dextral. Elements 1 - 7 and 10 - 12 are S elements, but as the coastae used to distinguish between the different element types are mainly obscured, they are hence simply termed ramiforms.

For convenience in referring to the relative orientations of the elements the posterior process of element 8, a P element, is taken to be horizontal. Element 1 is in the same orientation but elements 2 - 4 are at 80 - 90° to this orientation. Element 5 is again parallel to the P element. Only the posterior of elements 6 and 7 are visible but it is likely that the cusp and basal cavity of element 6 were in the same orientation as element 4 prior to their breakage. The posterior process of element 7 is sub-parallel to,



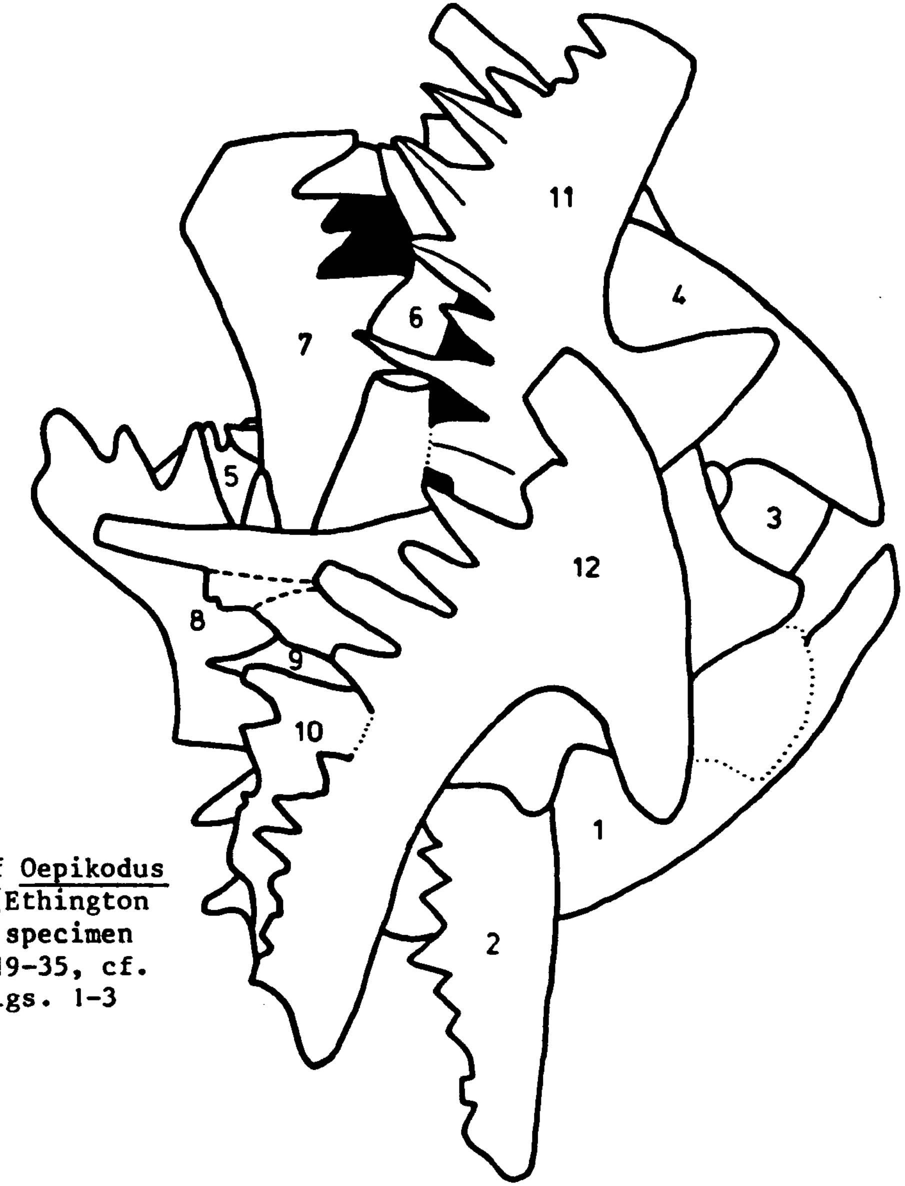


Fig. 7.2 Cluster of Oepikodus communis (Ethington & Clark), specimen number 5019-35, cf. pl. 19, figs. 1-3

but opposes, element 6; the cusp of this element is either concealed by other elements or missing.

Only three ramiform elements occur on the other side of the P element pair. Elements 10 and 12 are in the same orientation as one of the P elements (9) and element 11 is parallel but opposed. Small areas of the cluster below the basal cavity of element 12 and anterior to its cusp may belong to additional elements but it is not possible to be conclusive with so little exposed. There is no evidence for the presence of M elements within the cluster.

A second cluster of O. communis elements (Pl. 19, Fig. 4 ; GGU 240006) is probably composed of five ramiform elements although very poor preservation makes any estimate of the precise number rather equivocal. The uppermost element seen in Pl.19 Fig 1 bears a prominent costa on the lateral face and is probably an Sb or Sa element. The adjacent two elements also bear a strong costa down the side of the cusp. All elements have the same orientation.

7.4. CLUSTER OF DREPANOISTODUS SUBERECTUS (BRANSON AND MEHL, 1933)

A single cluster of D. suberectus was recovered from the Heim Bjerge Formation on Albert Heim Bjerge (Pl. 21, Figs 1, 2 ; GGU 239857). The cluster consists of four q elements in an excellent example of parallel-opposed orientation with the cusp tips interdigitated. The two elements on one side of the cluster have juxtaposed inner faces whilst those on the opposite side have the outer faces in contact. This arrangement of elements is highly unusual; in previously described coniform clusters each element has its outer face in contact with the inner face of the adjacent element.

7.5. CLUSTERS OF *PANDERODUS* sp. aff. *PANDERI* (STAUFFER, 1940)

Unlike the genera described above, fused clusters of *Panderodus* have been previously described. Pollock (1969) illustrated two clusters of the genus from the Silurian of Indiana; one of parallel-reversed type containing three elements and a second, rather disorganised, cluster also containing three elements.

Six clusters of *Panderodus*, ranging in composition from two to six elements, have been recovered from the Heim Bjerge Formation on Albert Heim Bjerge. Three of the clusters do not have opposed elements and consist simply of juxtaposed elements with the same orientation. Two of these (Pl. 21, Fig. 3 ; GGu 239863; Pl. 21, Figs 4, 5 ; GGU 239866) comprise just two arcuatiform elements (*sensu* Sweet, 1979) nested inner lateral face to outer lateral face. The cusps of the elements are too broken to permit observations regarding size gradations, but one of the clusters shows an apparent difference in recurvature between the elements (Pl. 21, Figs 4, 5). The third cluster (Pl. 22, Fig. 1 ; GGU 239859) consists of three elements which are nested and show a distinct decrease in size inwards. Another cluster containing three elements (Pl. 22, Fig. 2 ; GGU 239859) is too poorly preserved and disorganised to interpret, and may be coprolitic or fortuitous.

A fifth cluster consists of three asimiliform elements; two are in the same orientation but the third is parallel-reversed and lies obliquely across the anterior margin of the larger of the two opposing elements. Its basal cavity is adjacent to the outer tip of the opposing cusp and its cusp fused to the opposing inner base. (Pl. 22, Fig. 3).

The sixth, most complex, cluster comprises six elements (Pl. 22, Fig. 4 ; GGU 239868). Two small arcuatiform elements occur in a parallel-reversed position adjacent to the inner face of an arcuatiform or asimiliform element. This is in turn fused to the outer face of a falciform element which is in approximately the same orientation. Two arcuatiform/asimiliform elements complete the cluster. These are in approximately the same orientation as each other and are in a position transitional between parallel-reversed and parallel-opposed with respect to the falciform - arcuatiform/asimiliform pair. A point of interest is the 180^{o} difference in orientation between the small parallel-reversed pair of arcuatiforms and the openly parallel-reversed falciform - arcuatiform/asimiliform elements. This may be due to either post-mortem rearrangement of the elements or compaction of the head region of the animal at an oblique angle.

7.6. PALAEOBIOLOGICAL IMPLICATIONS

Recent debate on the function of the conodont apparatus has focused upon three alternative models; lophophore, tooth and supertooth. All of these models envisage conodont elements as part of a food-gathering structure. Lindström (1964, 1973, 1974) was the first to suggest that, since euconodonts are secreted internally, they may have acted as rigid supports for a tentacular food-gathering apparatus. Fine particulate food would be transported to the mouth by ciliated tentacles and grooves. A squat, barrel-shaped animal with external tentacles was envisaged (Lindström, 1973, 1974). The lophophorate hypothesis was supported and developed by Conway Morris (1976) who proposed Odontogriphus omalus from the Burgess Shale as a conodont animal. This animal was reconstructed as a flattened anulated worm with the tentaculate feeding apparatus arranged in a figure-of-eight shape about the mouth. Whilst this reconstruction may be sound, it is by no means certain that the cone-shaped moulds within the "tentaculate apparatus" represent conodonts. Bengtson (1983b) has suggested that O. omalus may be a lineage related to the paraconodonts although he admitted that there was insufficient corroboration to provide a firm link.

The tooth hypothesis was long favoured by many conodont workers, who interpreted them as part of the jaw apparatus of vertebrates (Pander, 1856; Ulrich and Bassler, 1926) or of an annelid-like group (Zittel and Rohon, 1886; Dubois, 1943). More recently, the tooth model has been reanalysed in terms of functional and comparative morphology. Jeppsson (1979) compared the morphology of conodont elements with the teeth of fish and reptiles, the radulae of cephalopods and the jaws of annelids and found a close morphological similarity. The apparent paradox of interal secretion and external use can be explained by Bengtson's(1976) suggestion that the conodont element was retracted into epithelial pockets when not in use, the epithelium being permanently attached only to the basal body. Jeppsson (1979) further observed that there are potentially three basic types of "bite"; teeth that meet and occlude, teeth that shear and teeth that do not meet but grasp.

On the basis of numerous fused clusters of the protoconodont "Prooneotodus" tenuis, Landing (1977) also suggested that the conodont apparatus might perform a grasping role. In order to overcome Lindström's (1974) objection regarding the weakness of individual elements and the lack of a broad attachment base, Landing (1977)proposed that each "half-apparatus" found in the clusters could have acted as a "supertooth". The strength of the supertooth would then be derived from the lateral association of elements and a broader attachment base would be obtained. It was suggested that the apparatus would have rested in a parallel-opposed position and that protrusion of the pharynx would have brought the superteeth into a parallel-reversed, grasping position. The model was extended by Tipnis and Chatterton (1979) who suggested that the elements of the superteeth were fused during life rather than in a post-mortem, diagenetic process.

Perhaps the most crucial work in resolving the conflict between these three models has been that of Szaniawski (1982). The similarity between the Chaetognatha and conodonts was first pointed out by Rietzchel (1973), but Szaniawski (1982) made a detailed morphological and histological comparison between individual elements and clusters of "P." tenuis and the spines of the recent chaetognath Sagitta. Morphologically the elements and spines are almost identical but they also have a very similar histology consisting of a thick, middle layer and thin outer and inner layers. In addition, the overall morphology of bundles of chaetognath spines when withdrawn into the hood is very similar to the half-apparatuses figured by Landing (1977). The only significant difference is that Sagitta spines are not phosphate, a fact to some extent countered by the very high organic content of protoconodonts (Szaniawski, 1983). Thus, it now seems almost certain that protoconodonts acted as grasping spines, ruling out the lophophore model, for this group at least.

The spines of chaetognaths spread apart when the hood is withdrawn (Szaniawski; 1982, text-Fig. 2A) and act as individual units. It would therefore seem likely that protoconodonts also acted as individual units, and not as superteeth, with preservation as half-apparatuses being due to early diagenesis whilst the elements were still constrained by the hood. The question which remains is the presence or absence of a relationship between protoconodonts and euconodonts or, alternatively, direct evidence for a link between chaetognaths and euconodonts.

Bengtson (1976) proposed a model for early conodont evolution which involves a transition from basal, internal secretion in protoconodonts, through external, concentric accretion in early growth stages in paraconodonts to external, concentric accretion at all stages in euconodonts. The critical link between different types of growth in proto- and euconodonts is the mode of secretion of paraconodonts. In these elements, the earliest growth stages were completely surrounded by tissue (Müller and Nogami, 1971) but then erupted free of it with subsequent growth being internal and around the exterior of the base. Bengtson (1976) hypothesised that the basal body of euconodonts is homologous with the entire protoconodont element. This homology was doubted by Szaniawski (1983) who suggested, in the light of his discovery of a three-layered structure in protoconodonts (Szaniawski, 1982, 1983), that if a homology did exist then it was probably between euconodont basal plates, paraconodont elements without their external organic cover and the inner and/or middle layers of protoconodonts. Therefore, although not disproved, a chaetognath/proto-/para-/euconodont relationship remains inconclusive from the structural evidence.

More direct evidence for a relationship between chaetognaths and euconodonts might be found in the soft-bodied fossil described from the Carboniferous of Scotland by Briggs et al. (1983). This animal has been accepted as the first convincing conodont animal with preserved soft parts (Bengtson, 1983a; Jeppsson and Löfgren, 1983) and many of its morphological features are reminiscent of chaetognaths (Briggs et al., 1983). The body is slender, with a constriction posterior to the head, possible lateral fins, axial traces of what might be a gut and a median line in the posterior part of the trunk reminiscent of the dorsoventral mesentry. However, these features could be reinterpreted in terms of a chordate body plan (Briggs et al., 1983) and Janvier (1983) considered the animal to be of myxinoid affinity. Bengtson (1983a) interpreted the arrangement of elements within the head of this specimen as indicating a non-functional resting position within an undilated pharynx and drew functional parallels with the chaetognath jaw apparatus. The evidence for a conodont/chaetognath relationship provided by the Scottish animal is equivocal, but it may be interpreted in terms of the model.

The fused clusters found in Greenland of the coniform genera "Scolopodus", Drepanoistodus and Panderodus show two marked similarities with clusters of "P." tenuis. First of these is the tendency for elements to occur in nested sets with the constituent elements showing a distinct graduation in size. The elements of "S." gracilis are stacked anterior margin to posterior margin with interlocking anterior and posterior margins. In contrast, Panderodus shows a more laterally directed nesting with the outer antero-lateral margin of one element fused to the postero-lateral face of the adjacent one. The cluster of Belodina figured by Barnes (1967) also displays lateral stacking with size decrease and Repetski (1980) reported that Cordylodus shows a similar pattern. Besselodus has laterally juxtaposed elements, but they are of consistent size (Aldridge, 1982). In each half of the grasping apparatus of Sagitta and "P." tenuis the median elements are the largest with the others decreasing in size to either side of the mid-line (Landing, 1977; Szaniawski, 1982). When found in their resting position, chaetognath elements are tightly packed and show a lateral nesting similar to that seen in these euconodont clusters.

The second, and more striking, resemblance to fused clusters of "P." tenuis is the occurrences of both parallel-opposed and parallel-reversed clusters. The cluster of D. suberectus provides a good example of the parallel-opposed orientation with its cusp tips interfingering. The clusters of both Panderodus and "S." gracilis show parallel-reversed arrangements. These strong resemblances between assemblages of protoconodonts and euconodonts would seem to indicate that there is a functional homology even if they should prove to be separate lineages.

The fused clusters also allow more specific observations regarding the overall morphology of the apparatuses concerned. The P elements of O. communis are preserved fused between sets of ramiforms. In other natural assemblages, mainly of Carboniferous age, the pairs of Pa and Pb elements lie in a discrete position posterior to the ramiforms (Briggs et al., 1983; Bengtson, 1983a). This may be an indication that the P elements in Oepikodus occupied a more anterior position or that they are not fully homologous with those in later apparatuses. A further observation is the lack of M elements, which have been interpreted as being part of the apparatus (Ethington and Clark, 1982; Repetski, 1982). Once again, this is probably indicative of a position separate from the main body of elements and corresponds well with other apparatuses, where the M elements flank the ramiform basket (Norby, 1976).

In summary, the fused clusters recovered from East Greenland provide a further test for the model proposing a chaetognath/conodont relationship (Bengtson, 1980, 1983a, b). They do not invalidate this model, and in many ways strengthen it. In particular, they show that coniform euconodonts were grouped into nested sets which show a gradational size decrease and that the elements were arranged in both parallel-opposed and parallel-reversed orientation. Even if the chaetognath model should eventually be rejected, the body of evidence indicates that euconodonts had a grasping apparatus analogous to that of chaetognaths and protoconodonts and that the lophophore and supertooth models should now be abandoned.

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APPENDIX I

Sample Numbers	Height (m)	Specimens per sample	Weight processed (g)	Specimens per kg processed
240038	1390m	8	752	10.8
—37	1380	1	502	2.0
—36	1360	0	1027	0
—35	1356	7	1050	6.7
—34	1345	3	1284	2.3
—33	1330	4	1131	3.5
—32	1314	2	646	3.1
—31	1314	3	1385	2.2
240030	1292	1	1200	0.8
—29	1276	0	1059	0
—28	1260	5	1717	2.9
—27	1254	0	580	0
—26	1232	5	1068	4.7
—25	1222	4	584	6.9
—24	1161	6	959	6.3
—23	1140	2	1178	1.7
—22	1126	1	1085	0.9
—21	1104	1	707	1.4
240020	1086	39	1236	31.6
—19	1060	2	681	2.9
—18	1052	2	1305	1.5
—17	1034	0	891	0
—16	1010	16	1038	15.4
—15	992	293	1024	286.1
—14	976	244	1165	209.4
—13	954	5	1303	3.8
—12	935	15	1378	10.9
—11	916	16	1093	14.6
240010	902	8	984	8.1
—09	880	192	1140	168.4
—08	868	353	695	507.9
—07	868	198	1068	185.4
—06	848	350	1222	286.4
—05	830	10	1293	7.7
—04	816	4	1240	3.2
—03	798	0	1289	0
—02	780	0	1384	0
—01	756	2	1347	1.5
240000	737	2	1323	1.5
—99	718	0	1064	0
—98	697	2	1514	1.3
—97	682	1	1107	0.9
—96	662	0	1240	0
—95	645	2	868	2.3
—94	630	4	1290	3.1
—93	616	1	632	1.6
—92	586	2	1041	1.9
—91	562	14	850	16.5
239990	543	5	1292	3.9
—89	514	1	720	1.4
—88	485	2	1555	1.3
—87	484	1	861	1.2
—86	470	2	926	2.2
—85	454	1	1196	0.8
—84	438	13	678	19.1
—83	424	12	741	16.2
—82	404	8	903	8.9
—81	384	10	1478	6.8
239980	368	1	1160	0.9
—79	342	23	1262	18.2
—78	326	2	1342	1.5
—77	306	8	912	8.8
—76	290	4	1202	3.3
—75	276	5	1295	3.9
—74	250	11	1238	8.9
—73	240	3	1392	2.2
—72	224	11	860	12.8
—71	210	9	1116	5.4
239970	190	27	993	27.2
—69	178	14	1160	12.1
—68	164	29	955	30.4
—67	150	6	1164	5.2
—66	134	14	1208	11.6
—65	98	0	1005	0
—64	78	8	1275	6.3
—63	64	4	863	4.6
—62	46	3	867	3.4
—61	28	2	1387	1.4
239960	15	31	986	31.4
—59	0m	2	1190	1.7
		2102	Total specimens	

Abundance table for section PF 770824-1, Ella Ø

Section	Sample Numbers	Height (m)	Amorphognathus ? sp A	Appalachignathus delicatulus					Belodella robusta				Belodella sp nov A			Belodina monitorensis		"Cordylodus" sp B				cordylodiform 1	Culumbodina sp A	Dapsilodus ? nevadensis			Drepanoistodus suberectus			eobeloniform 1	Erraticodon balticus					Erraticodon sp ? A	Glyptoconus aff G quadraplicatus	Multioistodus ? compressus				"Multioistodus" sp A	Oistodus ? angulatus	"Oistodus" sp nov B	Oulodus ? sp nov A				Panderodus aff P panderi		Paraprioniodus costatus						Phragmodus flexuosus						Pseudooneotodus sp	Pygodus anserinus	Pygodus sp	Sibiriodus ? kalakekus				Stereoconus cf S circulus	Trigonodus ? sinuosus				Wandelia fuscina			Gen nov B	Gen nov C	Specimens per sample	Weight processed (g)	Specimens per kg processed
				P	Sa	Sb	Sc	S?	tr	pl	bc	oi	tr	pl	bc	rastrate	eobel	M	Sa	Sb	Sc			bicost	sc	recurv	p	q	r		Pb	M	Sa	Sb	Sc	Past tert		M	Sa	Sb	Sc				Pa	Pb	Sb	Sc	cost	comp	Pa	Pb	M	Sa	Sc	Sb/Sd	P	M	Sa	Sb	Sc	Sd				sc	dr	oc	tr		sc	oc	tr	ds	Sa	Sb	Sc					
PF 770723-1	239901	Clast		3	3	2	1																2					1																	5	5	5	6	22	17																6	5	4	1											88	920	95.7
	239889	100							1			1																																					3																															5	—	—
	—90	90							1																																								2	1																														4	1168	3.4
	—91	80		2					2	2												1																					1						9	7																														24	1050	22.9
	—92	70		1				1	4	1	2	4				2										2																	1						20	8																														46	1425	32.3
	—93	60																																															2	6																	1													9	912	9.9
	—94	50										3												1																									2	2																														8	1071	7.5
	—95	40							1	3							1						1	3																			2						8	5																														24	1195	20.0
	—96	30		4					1		2						1							1																			1						7	5																														22	965	22.8
	—97	20							1			2				2																																	13	12																	1		1											32	795	40.3
	—98	10	1						6	2	1		2	1		2	2							5		1		3							1														45	23														1			1		1											98	864	101.7
	239899	0	2						1	1																																							2	1																														7	927	7.6
PF 770713-1	239872	690							2	1	1	1			1								2								2		1									1						12	9															1															34	4296	7.1
	—71	687							1	2	2												1					1	1																				23	5																														36	3030	11.9
	239870	685																																															10	3																														13	1432	9.1
	—69	675								1		1																1						1															5	3																														12	2116	5.7
	—68	669																																															12	4																														16	973	16.4
	—67	648																																															1																															1	1140	0.8
	—66	633								1														1				1																					7	5																														15	1020	14.7
	—65	619																																															11	5																														16	1154	13.9
	—64	604							1	1					1																																		6	4																														13	1390	9.4
	—63	590								1			1	1	1											1																							18	8																														31	1535	20.2
	—62	570							1																																								8	3																														12	1390	8.6
	—61	556																						2																									2																															4	1004	4.0
	239860	540								1																																							3																															4	1496	2.7
	—59	528																												1																			27	24																												1		53	1490	35.6
	—58	514																										2																					3	5																												1		11	1322	8.3
	—57	489																								1									1														5	1													1																	9	1085	8.3
	—56	476																						1		1				1																			6	2																														11	1625	6.8
	—55	464																													2																		5	6																														13	1573	8.3
	—54	448							2			2		2																																			10	6																														22	1514	14.5
	—53	438																						1																									2	4																														7	955	7.3
	—52	426																									1																						10	3																														14	1620	8.6
	—51	414																																															1	2																														3	1204	2.5
	239850	410									1																	2																					1	2																													1	7	1089	6.4
	—49	398									1	1																		1																			3	3																												1		10	1780	5.6
	—48	386							1			1																1															1						6	1																														11	1597	6.8
	—47	376																						2																									5	1																														8	1268	6.3
	—46	366																								1																							1																													1		3	1162	2.6
	—45	352								1	1	1																																					3	3																														9	1550	5.8
	—44	342							1	2	1																																1						6	1																														12	1246	9.6
	—43	331									1																																1						2																															4	1184	3.4
	—42	321										1												1		1		1																						3																														7	1470	4.8
	—41	310							4		1	1																3				1																																																10	875	11.5
	239840	308							1																																																																								1	1272	0.8
	—39	298							3		2	2													2				1						1														5																													1		17	1395	12.2
	—38	288							5	2	4	3													1	2			1																				8	3								1																						30	1443	20.8
	—37	278																										1						1																1																														3	1047	2.9
	—36	268																											1																																															1				2	939	2.1
	—35	258																			3																														2					1																1	1							8	1139	7.0
	—34	246																		1																															10		1	1	1	2																								16	1148	13.9
	—33	238																																			1																																											1	1756	0.6
	—32	226																																																																														0	1312	0
	—31	218																																																				1																										1	963	1.0
	239830	206																																																																														0	963	0
	—29	194																										1																																																				1	1388	0.7
	—28	181																																																																						1								1	908	1.1
	—27	168																1	1		6															3	1														4		2	5	6	3														1	4	2	2									41	884	46.4
	—26	158																																																					2	1																				1	7				11	879	12.5
	—25	146																2	1		8																														8	1	1	3	7	5															7	6	1									50	680	73.5
	—24	136																2	1																				1													1	5	2	1	6	6																1										26	1061	24.5
	—23	124																2		2	5															1								1							13		3	2	7	3																1	1									41	1343	30.5
	—22	110																1	1	5	12																					2									13		4	4	4																	3	2	1									52	1213	42.9
	—21	100																																																	3	15	5	8	22	15																								68	1272	53.5
	239820	85																		2																															2			1		1															2	1				1	1				11	1167	9.4
	—19	72																																																																														0	1587	0
	—18	36																			1																																																										9	9	45				64	1340	47.8
	—17	17																																																																									1	1	6				8	1290	6.2
	—16	6																																																																									2	2	5				9	1526	5.9
	—15	0																																																																									2	2	9				13	1068	12.2
	239873	Clast																										1																					4	2																														7	1584	4.4
			3	10	3	2	1	1	40	22	20	24	3	4	3	6	4	8	4	10	35	1	6	18	3	10	1	19	4	3	4	1	1	2	3	4	2	1	0	0	0	2	9	1	5	5	5	6	366	209	56	21	18	26	55	37	0	1	0	0	0	0	1	1	1	6	8	4	3	1	16	15	6	0	14	17	73	5	1	1280	Total specimens	

Abundance table for sections PF 770713-1, Albert Heim Bjerge, and PF 770723-1, C.H. Ostenfeld Nunatak

Sample Numbers	274934	274933	274932	274929	Total specimens
Height (m)	12				
"Acontiodus" sp. A	1				1
Drepanodus concavus arc.				6	6
Drepanodus concavus grac.					0
Drepanodus concavus pip.					0
Drepanodus concavus sculp.					0
Eucharodus parallelus	12	1		17	30
Glyptoconus quadraplicatus	3			21	24
Oneotodus costatus	5				5
Scandodus furnishi sensu Ethington and Clark				1	1
"Scandodus" sp. nov. A p					0
"Scandodus" sp. nov. A q					0
"Scandodus" sp. nov. A r				1	1
Tropodus comptus tricost.					0
Tropodus comptus quadri.					0
Tropodus comptus quinqui.	1				1
Tropodus comptus compt.					0
Ulrichodina abnormalis				2	2
Specimens per sample	22	1	0	48	71
Weight processed (g)	1670	1103	1296	861	
Specimens per kg processed	13.2	0.9	0	55.7	

Abundance tables for sections JSP 800630-5 and JSP 800630-6, Danmark Fjord

Total specimens	Element	Taxon
1		Oepikodus sp B
2		Oistodus bransoni
123		Oneotodus costatus
2		Oneotodus sp A
1		Protopanderodus elongatus
6		Protopanderodus gradatus
18		Protopanderodus leonardii
1	M	Protoprioniodus aranda
2	Ram	Protoprioniodus papiliosus
2	M	Protoprioniodus papiliosus
41	M	Pteracontiodus armillatus
24	Sa	Pteracontiodus armillatus
27	Sb	Pteracontiodus armillatus
27	Sc	Pteracontiodus armillatus
7	Sd	Pteracontiodus armillatus
1		Pteracontiodus ? sp A
5	p	Scalpellodus narvhalensis
4	p/qr	Scalpellodus narvhalensis
1	q	Scalpellodus narvhalensis
6	r	Scalpellodus narvhalensis
27		Scandodus furnishi sensu Ethington & Clark
102	p	Scandodus sp nov A
108	q	Scandodus sp nov A
78	r	Scandodus sp nov A
36		"Scolopodus" emarginatus
41		"Scolopodus" filosus
1006	s	"Scolopodus" gracilis
171	t	"Scolopodus" gracilis
150	u	"Scolopodus" gracilis
7		Scolopodus quadratus
30	tricost	Tropodus comptus
9	quadri	Tropodus comptus
31	quinqui	Tropodus comptus
27	compt	Tropodus comptus
45		Tropodus ? sp A
19		Tropodus sp B
13		Ulrichodina abnormalis
10		Ulrichodina wisconsinensis
1		Ulrichodina sp nov A
2		Ulrichodina sp nov B
1		Ulrichodina sp nov C
19		Weberina guyi
1		Weberina sp A
3403		Specimens per sample
		Weight processed (g)
		Specimens per kg processed

Total specimens	Element	Taxon
5		"Acontiodus" staufferi
2		"Acontiodus" sp A
1		"Acontiodus" sp B
3	seg	Bergstroemognathus extensus
3	Bipen	Bergstroemognathus extensus
1	Alate	Bergstroemognathus extensus
2	multi	Cristodus loxoides
2	mono	Cristodus loxoides
12	P	Diaphorodus delicatus
27	M	Diaphorodus delicatus
1	Sa	Diaphorodus delicatus
7	Sc	Diaphorodus delicatus
6	Sd	Diaphorodus delicatus
15	P	Diaphorodus sp A
28	M	Diaphorodus sp A
2	Sa	Diaphorodus sp A
11	Sc	Diaphorodus sp A
14	Sd	Diaphorodus sp A
15	arc	Drepanodus arcuatus
0	grac	Drepanodus arcuatus
17	pip	Drepanodus arcuatus
14	sculp	Drepanodus arcuatus
81	arc	Drepanodus concavus
43	grac	Drepanodus concavus
2	pip	Drepanodus concavus
24	sculp	Drepanodus concavus
5		Drepanodus sp C
0	p	Drepanoistodus anguiensis
6	q_1	Drepanoistodus anguiensis
0	q_2	Drepanoistodus anguiensis
2	r	Drepanoistodus anguiensis
15	p	Drepanoistodus suberectus
6	q	Drepanoistodus suberectus
7		Drepanoistodus sp A
11		Eucharodus apion
236		Eucharodus parallelus
14		Eucharodus toomeyi
10		Eucharodus xyron ?
134		Glyptoconus quadraplicatus
1		Histiodella ? sp B
1		Juanognathus variabilis
38		Macherodus lekiskus
38	P	Oepikodus communis
43	M	Oepikodus communis
25	Sa	Oepikodus communis
14	Sb	Oepikodus communis
38	Sc	Oepikodus communis
38	P	Oepikodus ? marathonensis
41	M	Oepikodus ? marathonensis
19	Sa	Oepikodus ? marathonensis
28	Sb	Oepikodus ? marathonensis
32	Sc	Oepikodus ? marathonensis

Abundance table for section JSP 800702-1, Danmark Fjord

Sample Numbers	Height (m)	Belodella robusta				Dapsilodus ? nevadensis			Drepanoistodus angulensis				Erismodus asymmetricus		Erraticodon balticus					Panderodus aff. P. panderi		Phragmodus flexuosus						Sibiriodus ? kalalekus				Trigonodus? sinuosus				Wandelia ? sp. nov A			Specimens per sample	Weight processed (g)	Specimens per kg processed
		tr	pl	bc	oi	bicost	sc	rec.	p	q_1	q_2	r	a	s	Pb	M	Sa	Sb	Sc	cost.	comp.	P	M	Sa	Sb	Sc	Sd	sc.	dr.	ac	tr	sc	ac	tr.	ds.	Sa	Sb	Sc			
274939	110													1																									1	1492	0.7
274941	67	1	4	4	1	4		1		2	1	3					1	1		12	3																		38	1067	35.6
274922	38	30	15	15	8				1	12	5	2		2								30	100	14	7	43	25	1	1										311	1128	275.7
274921	3																															2				9	7	4	22	1619	13.6
		31	19	19	9	4	0	1	1	14	6	5	0	3	0	0	1	1	0	12	3	30	100	14	7	43	25	1	1	0	0	2	0	0	0	9	7	4	372	Total specimens	

Abundance table for section JSP 800704-2, Danmark Fjord

Total specimens	Element	Taxon
4	tr	Belodella robusta
1	pl	Belodella robusta
1	bc	Belodella robusta
0	oi	Belodella robusta
2		Chosonodina rigbyi
2	M	"Cordylodus" sp B
0	Sa	"Cordylodus" sp B
0	Sb	"Cordylodus" sp B
4	Sc	"Cordylodus" sp B
1		Culumbodina sp A
0	p	Drepanoistodus angulensis
5	q1	Drepanoistodus angulensis
1	q2	Drepanoistodus angulensis
1	r	Drepanoistodus angulensis
2	past	Erraticodon? sp A
2	tert	Erraticodon? sp A
6		Glyptoconus aff G quadraplicatus
3	bry	Histiodella holodentata
0	int	Histiodella holodentata
1	sht bry	Histiodella holodentata
1		Leptochirognathus sp
[illegible]	Sa/Sb	Multioistodus aff M auritus
[illegible]	Sc	Multioistodus aff M auritus
40	M	Multioistodus? celox
27	Sa	Multioistodus? celox
64	Sb	Multioistodus? celox
73	Sc	Multioistodus? celox
24	Sd	Multioistodus? celox
5	M	Multioistodus? compressus
4	Sa	Multioistodus? compressus
7	Sb	Multioistodus? compressus
12	Sc	Multioistodus? compressus
6	Sd	Multioistodus? compressus
4		"Multioistodus" sp A
1		"Oistodus" sp nov B
0	Pa	Oulodus? sp nov A
0	Pb	Oulodus? sp nov A
1	Sb	Oulodus? sp nov A
0	Sc	Oulodus? sp nov A
9	Pa	Paraprioniodus costatus
0	Pb	Paraprioniodus costatus
6	M	Paraprioniodus costatus
4	Sa	Paraprioniodus costatus
13	Sc	Paraprioniodus costatus
5	Sb/Sd	Paraprioniodus costatus
3	P	Phragmodus flexuosus
5	M	Phragmodus flexuosus
2	Sa	Phragmodus flexuosus
3	Sb	Phragmodus flexuosus
4	Sc	Phragmodus flexuosus
0	Sd	Phragmodus flexuosus
11		Scandodiform 1
8	sc	Trigonodus? sinuosus
3	ac	Trigonodus? sinuosus
1	tr	Trigonodus? sinuosus
1	ds	Trigonodus? sinuosus
21		"Acontiodus" staufferi
1		"Acontiodus" sp A
6		"Acontiodus" sp B
2	ma	Cristodus loxoides
2	mu	Cristodus loxoides
77	arc	Drepanodus concavus
36	grac	Drepanodus concavus
15	pip	Drepanodus concavus
31	sculp	Drepanodus concavus
2		Drepanodus? costatus
2		Drepanodus sp C
9	p	? Drepanoistodus suberectus
16	q	? Drepanoistodus suberectus
151		Eucharodus parallelus
1		Eucharodus toomeyi
20		Eucharodus xyron ?
466		Glyptoconus quadraplicatus
49		Oneotodus costatus
1		"Oneotodus" mitra
4		Protopanderodus cf P gradatus
1	M	Pteracontiodus armillatus
[illegible]	Sa	Pteracontiodus armillatus
[illegible]	Sb	Pteracontiodus armillatus
2	Sc	Pteracontiodus armillatus
0	Sd	Pteracontiodus armillatus
40		Scandodus furnishi sensu Ethington and Clark
22	P	"Scandodus" sp nov A
51	a	"Scandodus" sp nov A
35	r	"Scandodus" sp nov A
8		"Scolopodus" emarginatus
13	s	"Scolopodus" gracilis
1	t	"Scolopodus" gracilis
4	u	"Scolopodus" gracilis
13	tricost	Tropodus comptus
20	quadri	Tropodus comptus
12	quinqui	Tropodus comptus
19	compt	Tropodus comptus
2		Tropodus? sp A
37		Ulrichodina abnormalis
1		Ulrichodina wisconsinensis
3		Weberina guyi
7		Gen nov A sp nov B

Sample Number: 226394, 95, 96, 97, 98, 99, 226400, 227801, 02, 03, 04, 05, 06, 07, 08, 09, 227810, 227819, 20, 21, 22, 23, 227824, 227811, 12, 13, 14, 15, 16, 17, 227818

Height (m): 4, 9, 23, 30, 46, 53, 62, 71, 80, 85, 96, 105, 114, 121, 128, 140, 147, 149, 153, 166, 177, 184, 195, 214, 221, 239, 257, 263, 272, 286, 297

Specimens per sample (Total specimens 1600): [illegible], 85, 1, 144, 4, 0, 5, 3, 6, 0, 1, 0, 15, 19, 20, 5, 5, 0, 0, 57, 1, 5, 4, 247, 35, 22, 0, 0, 0, 27, 1

Weight processed (g): 2732, 2270, 2263, 1746, 1800, 1037, 1717, 1978, 2047, 2337, 2394, 1700, 2672, 1535, 2143, 2299, 2032, 1566, 1937, 2077, 1535, 2082, 1856, 2010, 2286, 1647, 500, 700, 1363, 1552, 1365

Specimens per kg processed: 325.0, 37.4, 0.4, 82.4, 2.5, 0, 2.9, 1.6, 2.9, 0, 0.4, 0, 5.6, 12.4, 9.3, 2.2, 2.5, 0, 27.4, 0.7, 2.4, 2.2, 122.9, 15.3, 13.4, 0, 0, 0, 17.4, 0.7

Abundance table for section JEM 790627-1, central Peary Land

Section	Sample Numbers	Height (m)	Appalachignathus delicatulus					Belodella robusta				Belodella? sp nov A			Cordylodus sp B				Columbodina sp A	Drepanoistodus angulensis				Erismodus asymmetricus		Erraticodon balticus					Erraticodon? sp A		Histiodella holodentata			Multioistodus aff M auritus		Oistodus sp nov B
			P	Sa	Sb	Sc	S?	tr	pl	bc	d	tr	pl	br	M	Sa	Sb	Sc		P	q	q?	r	o	s	Pb	M'	Sa	Sb	Sc	pas'	tert	b'y	inter	gm b'y	Sa/Sb	Sc	
A	227033	57	1		2																																	
	—34	55	5	1						1														1	1													
	—35	51	2	1	1	1		4	2		2								4		1		1															
	—36	48	3	3	2	1	1	1	1	1			1						2	1	7		2					1										
	—37	37	1	1				3	4	2	2	1								2	5						1											
	—38	19																																				
	—39	0																																				
B	227058	118																																				
	—57	116	1																																			
	—56	114																																				
	—55	112																																				
	—54	102																																				
	—53	91																																				
	—52	81																			1	1	1															
	—51	70																																				
	227050	50						1																														
	—49	40																																				
	—48	30								1										2	7	1	1	1				1										
	—47	22															2	1																				
	—46	12													2	1	4	6													2	3						
	227045	0														3	4	2			1		1								1		16	4	3		5	3
			13	6	5	2	1	9	7	5	4	1	1	0	2	4	10	9	6	5	22	2	6	2	1	0	1	2	0	0	3	3	16	4	3	0	5	3

Section	Sample Numbers	Height (m)	Panderodus aff P panderi		Paraprioniodus costatus						Phragmodus flexuosus						Phragmodus sp nov A		Phragmodus sp	Plectodina? sp A			Sibiriodus? kalolekus				Trigonodus? sinuosus				Wandelia fuscina			Specimens per sample	Weight processed (g)	Specimens per kg processed
			cost	comp	Pa	Pb	M	Sa	Sc	Sb/Sd	P	M	Sa	Sb	Sc	Sd	M	Sc		Pa	Sb	Sc	sc	dr	bc	tr	sc	bc	tr	ds	Sa	Sb	Sc			
A	227033	57																																3	2030	1.5
	—34	55	12	5																	2	2	50	17	20	5								122	1546	78.9
	—35	51	24	20																			7	4		3								77	1587	48.5
	—36	48	8	8																	1	4		2		1								51	1458	34.9
	—37	37	12	21																1	2	4		1	1	2								66	1985	33.2
	—38	19																						1										1	1960	0.5
	227039	0									3	5	2	3	4																	2		19	1710	11.1
B	227058	118																																0	1778	0
	—57	116																																1	1906	0.5
	—56	114																																0	1007	0
	—55	112	1	1																			1	1										4	1455	2.7
	—54	102	6	2													2	1				1	1	1	2	2						1	5	24	1530	15.7
	—53	91	1	1																				4										6	1399	4.3
	—52	81	7	5															9				1	3	2									30	1428	21.0
	—51	70																		4		3												7	1724	4.0
	227050	50																													1	3		5	1971	2.5
	—49	40																						1										1	1722	0.6
	—48	30									11	18	3	5	21	5																		77	1836	41.9
	—47	22			2	1			4																			1						11	1593	6.9
	—46	12			14	4	19	5	25	19																	5	3	1					113	1769	63.9
	227045	0			17	7	2	8	49	26																	13	5			1			171	2118	80.9
			71	63	33	12	21	13	78	45	14	23	5	8	25	5	2	1	9	5	5	14	60	35	25	13	18	9	1	0	2	6	5	789	Total specimens	

Abundance tables for sections JEM 790627-2 (A) and JEM 790701-1 (B), central Peary Land

Taxon	Element	271641	271671	271670	69	68	67	66	65	64	63	62	61	271659	58	57	55	Total
Height (m)		135	129	119	108	97	96	88	79	76	66	56	45	37	29	21	11	
Appalachignathus delicatulus	P	1																1
	Sa																	0
	Sb																	0
	Sc																	0
	S?																	0
"Cordylodus" sp. B	M													1				1
	Sa											3						3
	Sb											2						2
	Sc											3		3				6
Paraprioniodus costatus	Pa											10		3				13
	Pb											4		1				5
	M											4		5				9
	Sa											4		3		1		8
	Sc											12	1	12				25
	Sb/Sd											7		6		1		14
Sibiriodus? kalalekus	sc.	2		2														4
	dr.	3																3
	ac.	1		1														2
	tr.																	0
Trigonodus? sinuosus	sc													3				3
	ac				1													1
	tr.																	0
	dc.																	0
Wandelia fuscina	Sa					2									1			3
	Sb					2	1											3
	Sc					2												2
Specimens per sample		7	0	3	1	6	1	0	0	0	0	49	1	37	1	2	0	108
Residues Only																		

Abundance tables for sections JSP 780711-1 and 780711-2, western Peary Land

PLATES

PLATE 1

Figs 1, 2 "Acontiodus" staufferi Furnish

1, postero-lateral view, 5255-78, x40, GGU 274959,

2, posterior view, 5255-77, x60, GGU 226394.

Fig. 3 "Acontiodus" sp. A.

3, posterior view, 5255-79, x60, GGU 274958.

Fig. 4. "Acontiodus" sp. B.

4, postero-lateral view, 5256-85, x60, GGU 226394.

Figs 5, 6 Amorphognathus? sp. A.

5, upper view, 5302-5, x60, GGU 239898,

6, lower view, 5302-5, x60, GGU 239898.

Figs 7 - 13 Appalachignathus delicatulus Bergström et al.

7, lateral view of P element, 5178-97, x40, GGU 227835,

8, posterior view of Sa element, 5178-98, x60, GGU 227835,

9, postero-lateral view of Sb element, 5178-99, x60, GGU 227836,

10, postero-lateral view of Sb element, 5169-1, x60, GGU 227835,

11, lateral view of Sc element, 5178-1, x60, GGU 227836,

12, posterior view of Sc element, 5178-1, x60, GGU 227836

13, lateral view of ?S element, 5179-2, x60, GGU 227936.

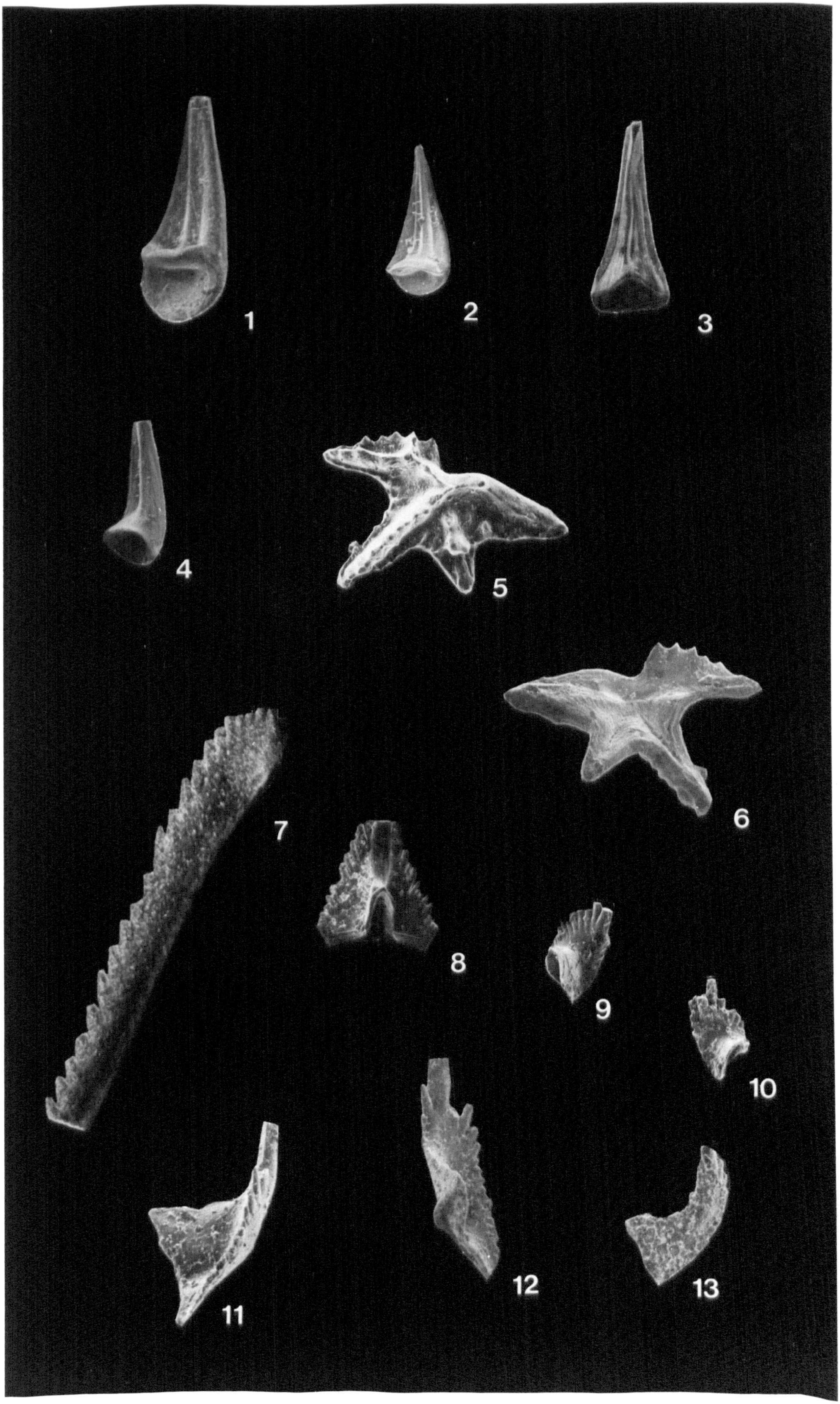
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PLATE 2

Figs 1 - 8 Belodella robusta Ethington and Clark

1, lateral view of triangular element, 4734-13, x60, GGU 239890,

2, lateral view of triangular element, 5176-89, x60, GGU 274922,

3, inner lateral view of plano-convex element, 5176-91, x60, GGU 239844,

4, inner lateral view of biconvex element, 5177-92, x60, GGU 274922,

5, outer lateral view of biconvex element, 5177-92, x60, GGU 274922,

6, inner lateral view of oistodiform element, 4734-14, x60, GGU 239839,

7, inner lateral view of oistodiform element, 5177-93, x60, GGU 274922,

8, outer lateral view of oistodiform element, 5177-93, x60, GGU 274922.

Figs 9 - 11 Belodella? sp. nov. A.

9, lateral view of triangular element, 5177-94, x60, GGU 239898,

10, lateral view of plano-convex element, 5177-95, x60, GGU 239863,

11, lateral view of biconvex element, 5188-73, x60, GGU 239864,

Figs 12, 13 Belodina monitorensis Ethington and Schumacher

12, inner lateral view of rastrate element, 4732-5, x60, GGU 239897,

13, outer lateral view of eobelodiniform element, 5301-2, x100, GGU 239896,

Figs 14, 15 eobelodiniform 1

14, inner lateral view, 5396-42, x100, GGU 239859,

15, inner lateral view, 5396-43, x60, GGU 239856.

Figs 16 - 22 Bergstroemognathus extensus (Graves and Ellison)

16, inner lateral view of P element, 4737-34, x40, GGU 240011,

17, posterior view of Sa element, 4736-33, x60, GGU 240014,

18, inner lateral view of S element, 5257-89, x60, GGU 240015,

19, lateral view of S element, 5257-87, x60, GGU 240014,

20, lateral view of S element, 5345-79, x60, GGU 240014,

21, lateral view of S element, 5257-88, x60, GGU 240015,

22, lateral view of S element, 5257-86, x60, GGU 240013.

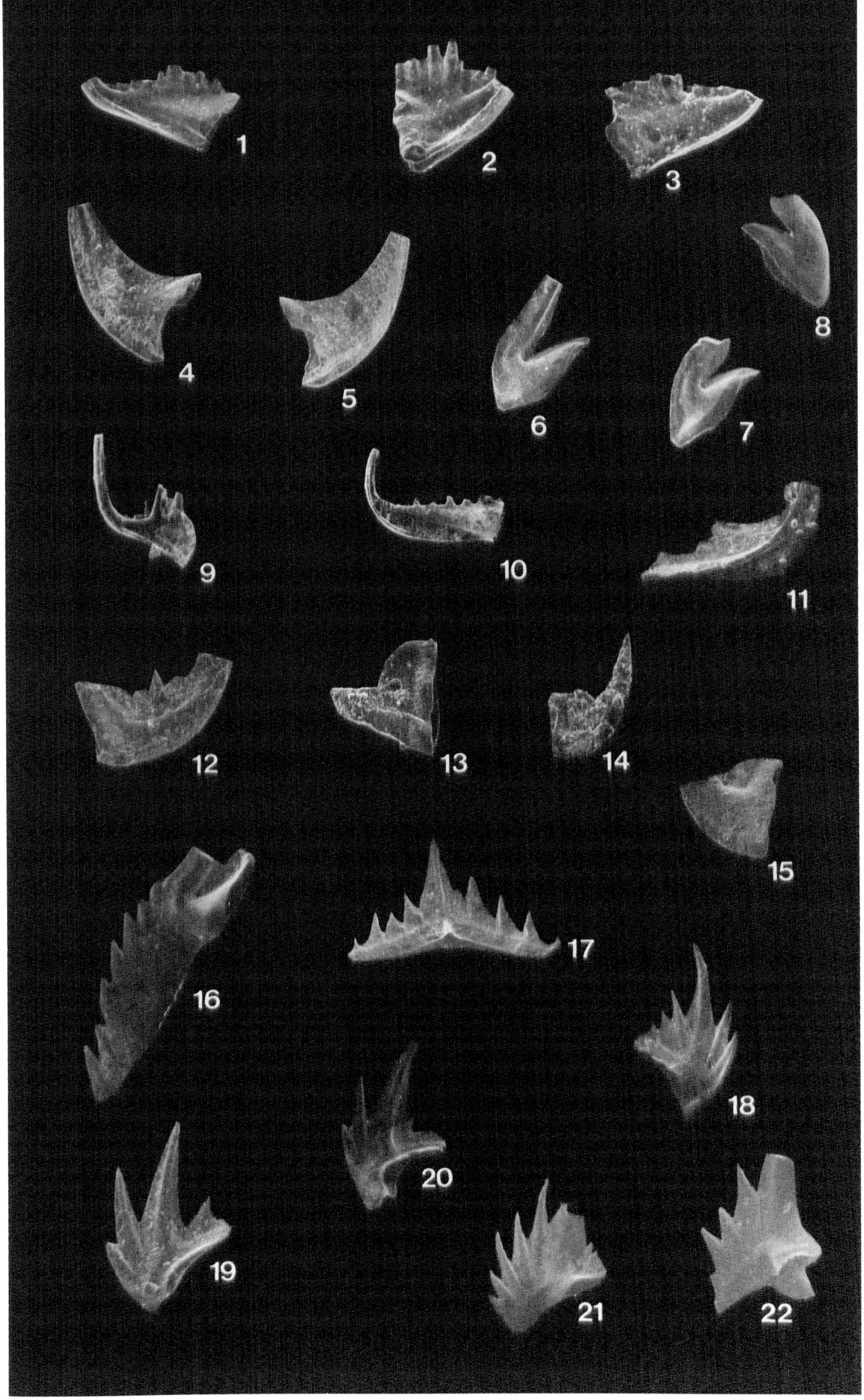
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PLATE 3

Fig. 1 Chosonodina rigbyi Ethington and Clark

1, anterior view, 5188-74, x60, GGU 227821.

Fig. 2 Cordylodus sp. nov. A.

2, inner lateral view, 5258-93, x100, GGU 239960.

Figs 3 - 9 "Cordylodus" sp. B.

3, lateral view of Sa element, 5171-12, x40, GGU 239820,

4, opposite lateral view of Sa element, 5171-12, x40, GGU 239820,

5, outer lateral view of Sb element, 4619-7, x40, GGU 239822,

6, inner lateral view of Sb element, 4619-6, x40, GGU 239822,

7, lateral view of Sc element, 4619-7, x40, GGU 227845,

8, inner lateral view of M element, 5171-11, x40, GGU 239822,

9, outer lateral view of M element, 5171-11, x40, GGU 239822.

Fig. 10 Cordylodiform 1

10, lateral view, 5303-8, x100, GGU 239891.

Figs 11 - 13 Cristodus loxoides Repetski

11, inner lateral view of multidenticulate element, 5258-96, x60, GGU 274958,

12, outer lateral view of multidenticulate element, 5258-96, x60, GGU 274958,

13, inner lateral view of monodenticulate element, 5258-95, x60, GGU 274945.

Fig. 14 Cristodus? sp. A.

14, lateral view, 5259-30, x60, GGU 239977.

Figs 15 - 17 Culumbodina sp. A.

15, outer lateral view, 5302-3, x60, GGU 227835,

16, inner lateral view, 5302-3, x60, GGU 227835,

17, inner lateral view, 5302-4, x60, GGU 239901.

Fig. 18 Dapsilodus? nevadensis (Ethington and Schumacher)

18, lateral view of scandodiform element, 5300-37, x60, GGU 239839.

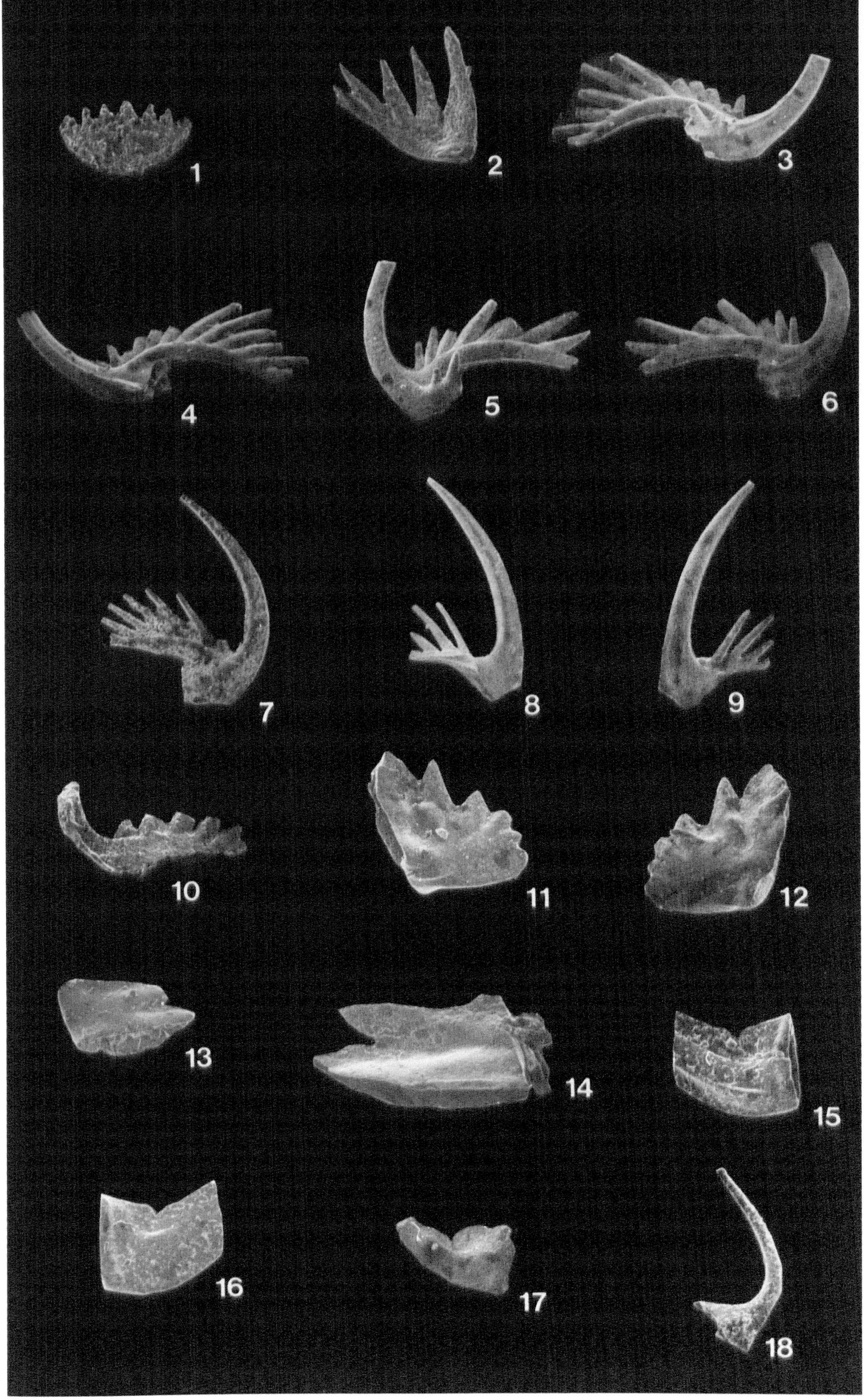
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PLATE 4

Figs 1 - 5 Diaphorodus delicatus (Branson and Mehl)

1, outer lateral view of P element, 5259-31, x60, GGU 240020,

2, inner lateral view of M element, 5259-32, x60, GGU 240020,

3, posterior view of Sa element, 5259-33, x60, GGU 240020,

4, lateral view of Sc element, 5259-34, x60, GGU 240020,

5, lateral view of Sd element, 5259-35, x60, GGU 240020.

Figs 6, 7 Diaphorodus? russoi (Serpagli)

6, lateral view of Sa element, 5260-36, x60, GGU 240015,

7, lateral view of M element, 5260-37, x100, GGU 240015.

Figs 8 - 12 Diaphorodus sp. nov. A.

8, outer lateral view of P element, 5261-40, x60, GGU 274958,

9, lateral view of M element, 5261-41, x60, GGU 274958,

10, antero-lateral view of Sa element, 5261-42, x100, GGU 274958,

11, lateral view of Sc element, 5261-43, x60, GGU 274958,

12, postero-lateral view of Sd element, 5261-44, x60, GGU 274958.

Figs 13 - 17 Diaphorodus? sp. B.

13, outer lateral view of P element, 5262-45, x60, GGU 240006,

14, inner lateral view of M element, 5262-47, x60, GGU 240007,

15, lateral view of Sa element, 5262-48, x60, GGU 240006,

16, lateral view of Sc element, 5262-49, x60, GGU 240008,

17, lateral view of Sd element, 5263-50, x60, GGU 240008.

Figs 18 - 20 Drepanodus arcuatus Pander

18, inner lateral view of arcuatiform element, 5263-53, x60, GGU 240006,

19, lateral view of sculponeaform element, 4735-17, x60, GGU 240006,

20, lateral view of pipaform element, 5263-52, x60, GGU 240015.

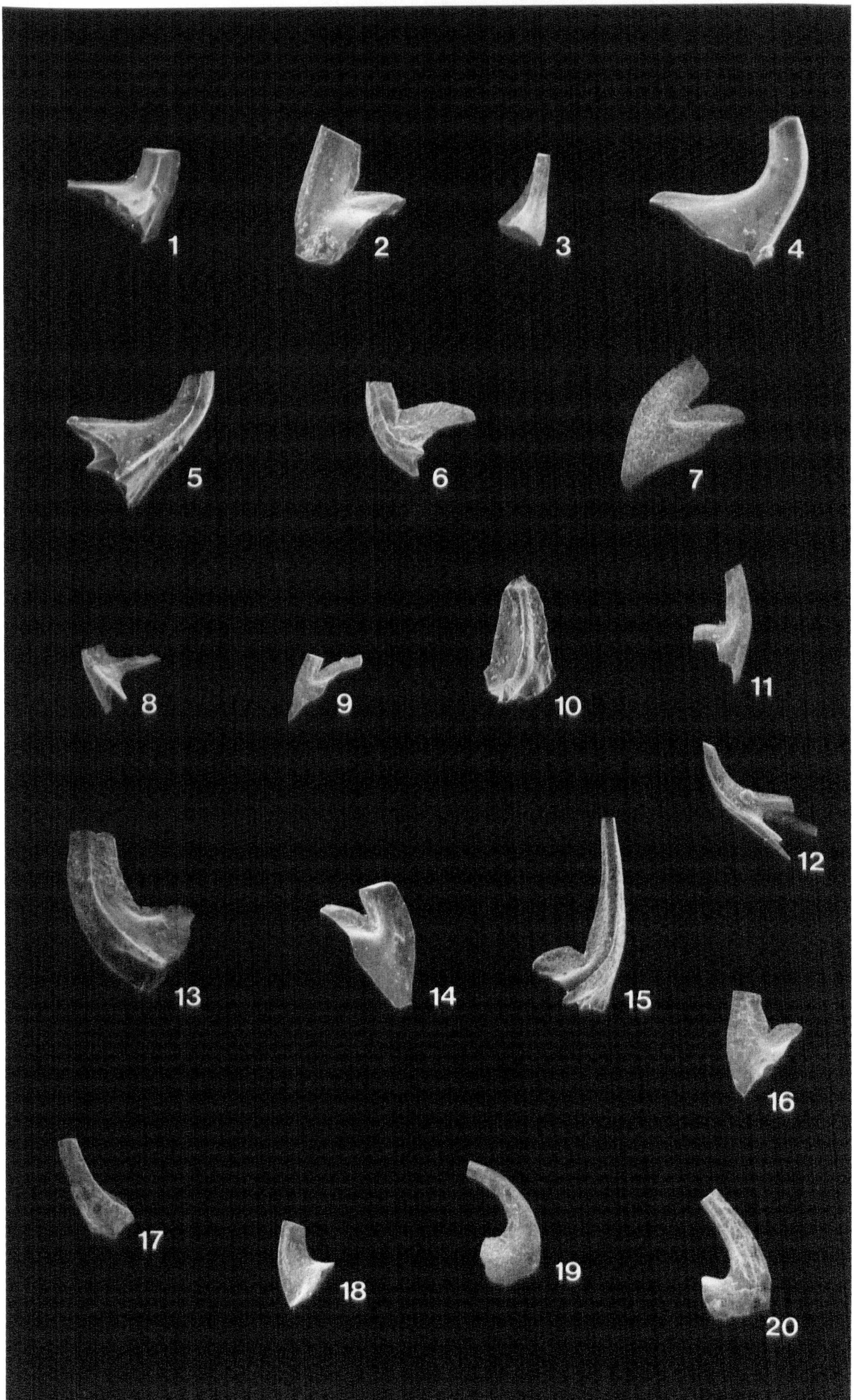
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PLATE 5

Figs 1 - 10 — *Drepanodus concavus* (Branson and Mehl)

1, inner lateral view of arcuatiform element, 5263-54, x40, GGU 226394,

2, inner lateral view of arcuatiform element, 5264-55, x40, GGU 226397,

3, outer lateral view of arcuatiform element, 5264-55, x40, GGU 226397,

4, outer lateral view of sculponeaform element, 5265-61, x40, GGU 274956,

5, inner lateral view of sculponeaform element, 5265-61, x40, GGU 274956,

6, outer lateral view of sculponeaform element, 5264-56, x40, GGU 226397,

7, outer lateral view of graciliform element, 5264-58, x40, GGU 226394,

8, outer lateral view of graciliform element, 5264-59, x40, GGU 226397,

9, inner lateral view of pipaform element, 5265-60, x40, GGU 226397,

10, outer lateral view of pipaform element, 5265-60, x40, GGU 226397.

Fig. 11 — *Drepanodus costatus* Abaimova

11, lateral view, 5266-10, x40, GGU 239982.

Fig. 12 — "*Drepanodus*" sp. A.

12, lateral view, 5266-11, x60, GGU 239960.

Fig. 13 — "*Drepanodus*" sp. B.

13, lateral view, 5266-12, x40, GGU 239991.

Figs 14, 15 — "*Drepanodus*" sp. C.

14, inner lateral view, 5266-13, x40, GGU 274956,

15, outer lateral view, 5266-13, x40, GGU 274956.

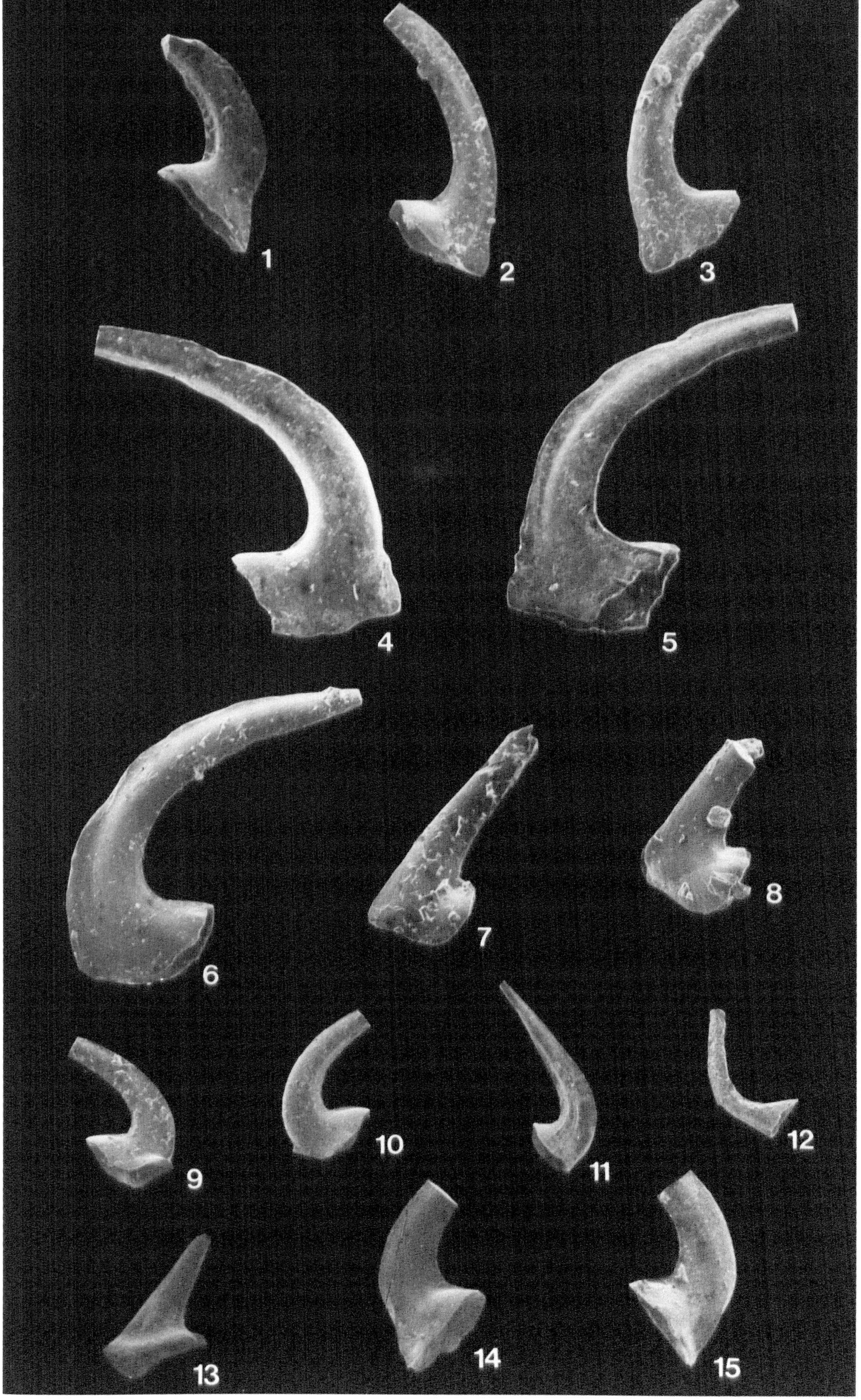
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PLATE 6

Figs 1 - 4 Drepanoistodus angulensis (Harris)

1, lateral view of p element, 5394-32, x60, GGU 227837,

2, inner lateral view of q_1 element, 5394-35, x60, GGU 274922,

3, outer lateral view of q_2 element, 5394-33, x60, GGU 274922,

4, inner lateral view of r element, 5395-37, x60, GGU 227835.

Figs 5 - 7 Drepanoistodus aff. D. forceps (Lindström)

5, lateral view of p element, 5266-14, x60, GGU 240006,

6, inner lateral view of q element, 5267-15, x60, GGU 240008,

7, inner lateral view of r element, 5267-17, x60, GGU 240009.

Figs 8 - 10 Drepanoistodus suberectus (Branson and Mehl)

8, inner lateral view of q element, 5395-40, x60, GGU 239829,

9, inner lateral view of q element, 5395-41, x40, GGU 239850,

10, outer lateral view of r element, 5395-39, x60, GGU 239835.

Figs 11, 12 ?Drepanoistodus suberectus (Branson and Mehl)

11, lateral view of p element, 5267-18, x60, GGU 274944,

12, inner lateral view of q element, 5267-19, x60, GGU 226394.

Fig. 13 Drepanoistodus sp. A.

13, inner lateral view of r element, 5268-20, x100, GGU 274944.

Figs 14, 15 Erismodus asymmetricus (Branson and Mehl)

14, lateral view of asymmetrical element, 5396-44, x60, GGU 227848,

15, posterior view of symmetrical element, 5396-45, x40, GGU 274922.

Figs 16 - 21 Erraticodon balticus Dzik

16, lateral view of Pb element, 4733-9, x40, GGU 239872,

17, inner lateral view of M element, 5176-88, x60, GGU 227837,

18, lateral view of Sa element, 4733-10, x40, GGU 239872,

19, postero-lateral view of Sb element, 5176-87, x40, GGU 239869,

20, antero-lateral view of Sb element, 5176-87, x40, GGU 239869,

21, outer lateral view of Sc element, 4733-8, x40, GGU 239898.

Figs 22, 23 Erraticodon? sp. A.

22, lateral view of pastinate element, 5172-20, x60, GGU 227846,

23, posterior view of tertiopedate element, 5172-22, x60, GGU 227846.

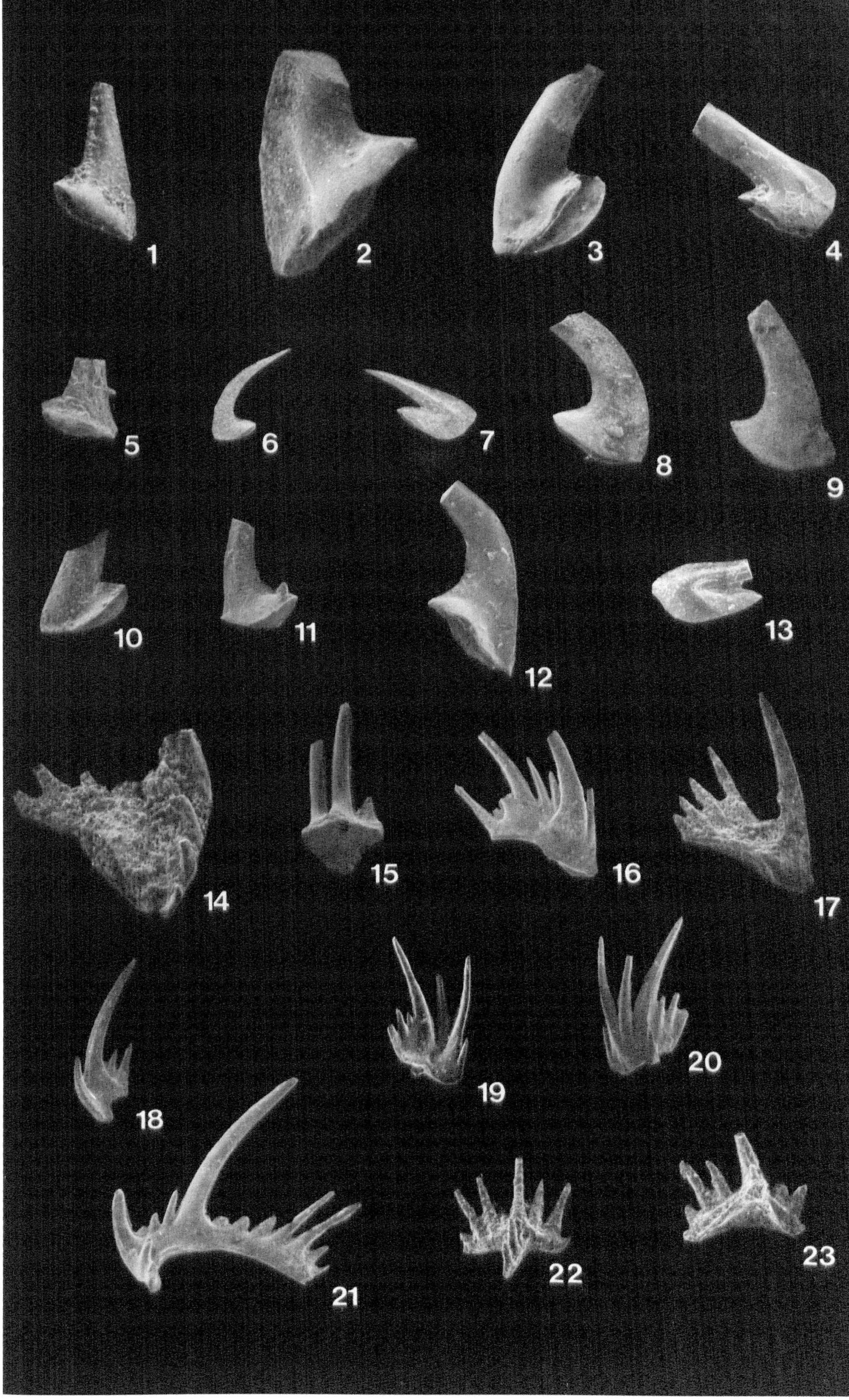
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PLATE 7

Figs 1 - 3 — Eucharodus apion sp. nov.

1, inner lateral view (holotype), 5268-21, x40, GGU 274945,

2, outer lateral view (holotype), 5268-21, x40, GGU 274945,

3, outer lateral view (paratype), 5268-22, x60, GGU 274944.

Figs 4 - 6 — Eucharodus parallelus (Branson and Mehl)

4, lateral view, 5268-23, x40, GGU 274959,

5, opposite lateral view, 5268-23, x40, GGU 274959,

6, lateral view, 5268-24, x40, GGU 274944.

Fig. 7 — Eucharodus toomeyi (Ethington and Clark)

7, inner lateral view, 5345-80, x40, GGU 239983.

Figs 8, 9 — Eucharodus xyron (Repetski)?

8, lateral view, 5269-25, x60, GGU 226397,

9, lateral view, 5269-26, x60, GGU 226397.

Figs 10 - 12 — "Fryxellodontus" sp. A.

10, lateral view, 5269-27, x100, GGU 240014,

11, upper view, 5269-28, x100, GGU 240014,

12, upper view, 5269-29, x100, GGU 240014.

Figs 13 - 16 — Glyptoconus quadraplicatus (Branson and Mehl)

13, lateral view of quadricostate element, 5270-30, x40, GGU 226394,

14, lateral view of tricostate element, 5270-31, x 60, GGU 226394,

15, opposite lateral view of tricostate element, 5270-31, x60, GGU 226394,

16, lateral view of element with bifid costae, 5270-32, x40, GGU 274956.

Figs 17, 18 — Glyptoconus aff. G. quadraplicatus (Branson and Mehl)

17, lateral view, 5195-95, x60, GGU 227824,

18, lateral view, 5195-96, x60, GGU 239833.

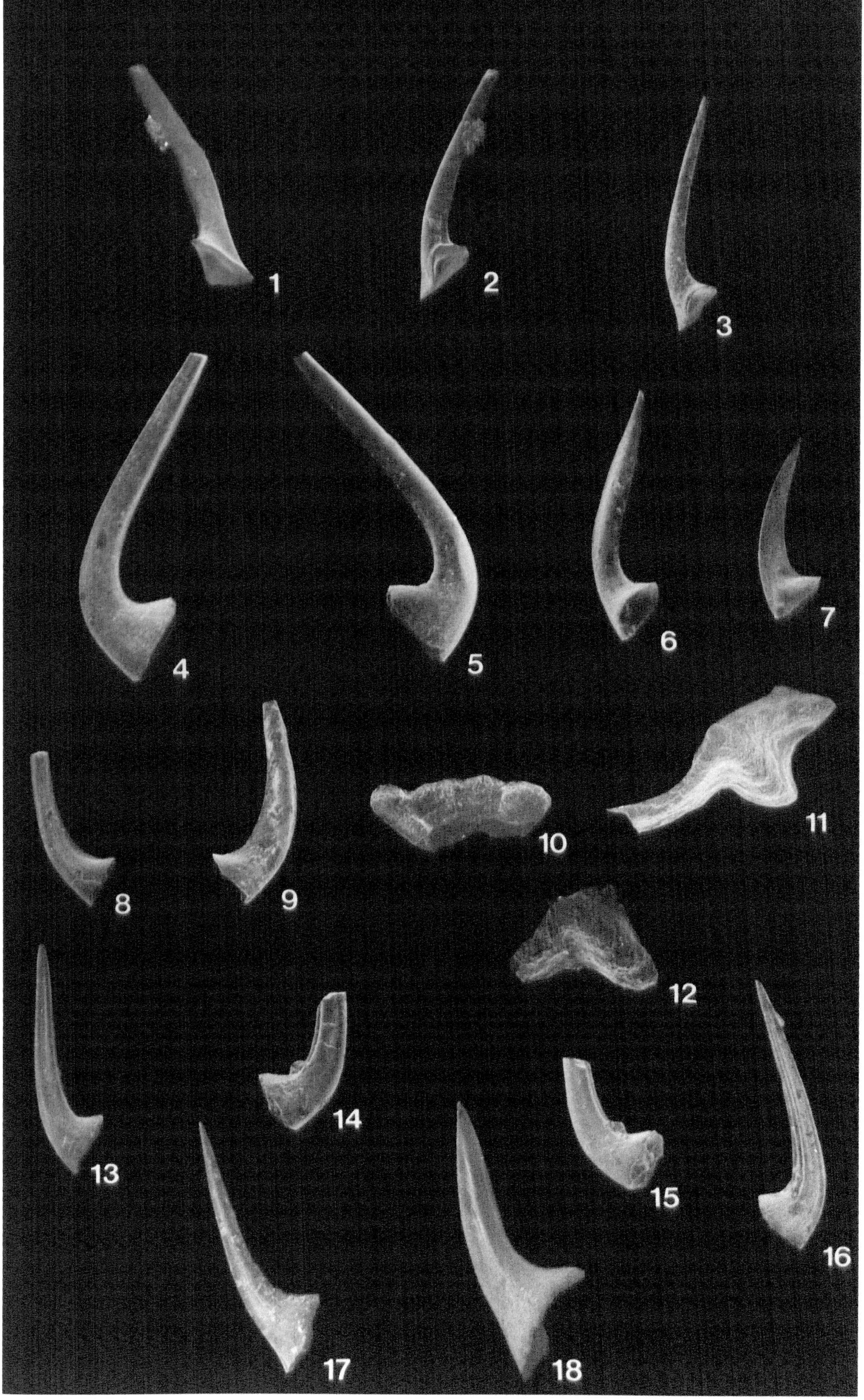
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PLATE 8

Figs 1 - 5 — Histiodella holodentata Ethington and Clark

1, lateral view of bryantodiform element, 5171-15, x100, GGU 227845,

2, lateral view of bryantodiform element, 5171-16, x100, GGU 227845,

3, lateral view of intermediate element, 5171-17, x100, GGU 227845,

4, lateral view of short bryantodiform element, 5171-18, x100, GGU 227845,

5, lateral view of short bryantodiform element, 5171-19, x100, GGU 227845.

Fig. 6 — Histiodella sp. A.

6, posterior view, 5270-33, x100, GGU 240009.

Fig. 7 — Histiodella? sp. B.

7, lateral view, 5270-34, x100, GGU 274945.

Figs 8, 9 — Juanognathus variabilis Serpagli

8, postero-lateral view, 5271-35, x60, GGU 240012,

9, postero-lateral view, 5271-36, x60, GGU 240019.

Fig. 10 — Juanognathus sp. nov. A.

10, postero-lateral view, 5271-37, x60, GGU 240008.

Fig. 11 — Jumudontus gananda Cooper

11, lateral view, 4892-32, x60, GGU 240006.

Fig. 12 — Leptochirognathus sp.

12, lateral view, 5194-94, x60, GGU 227823.

Figs 13, 14 — Macheticodus carlae (Repetski)

13, posterior view, 5271-39, x60, GGU 240014,

14, anterior view, 5271-39, x60, GGU 240014.

Figs 15 - 18 — Macheticodus lekiskus gen. et sp. nov.

15, anterior view (holotype), 5273-52, x40, GGU 274944,

16, anterior view (paratype), 5272-41, x40, GGU 274944,

17, posterior view (paratype), 5272-40, x60, GGU 274944,

18, anterior view (paratype), 5272-40, x60, GGU 274944,

Fig. 19 — Multioistodus auritus Harris and Harris

19, antero-lateral view, 4735-21, x60, GGU 240037.

Fig. 20 — Multioistodus aff. M. auritus Harris and Harris

20, lateral view, 5192-94, x100, GGU 227845.

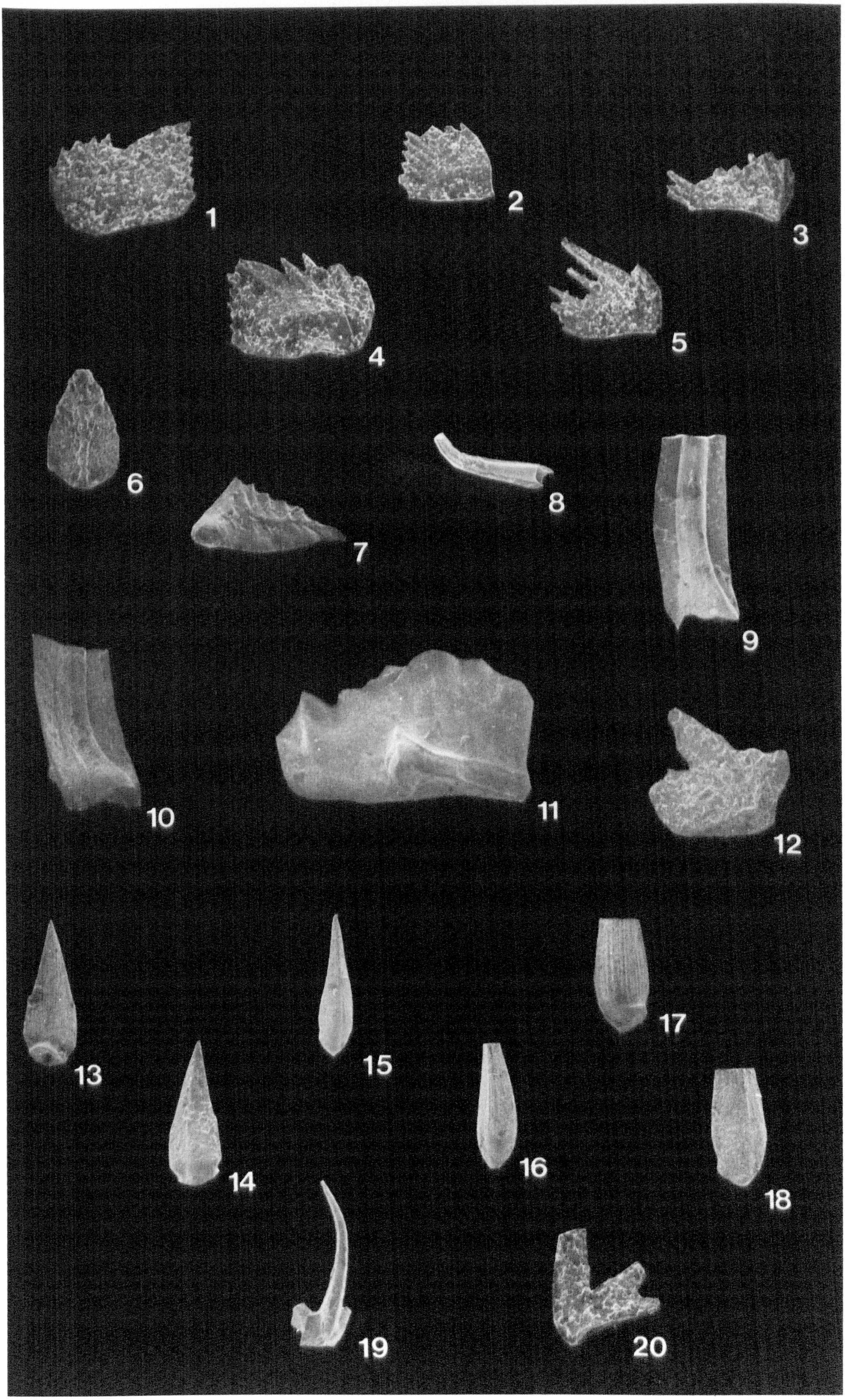

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PLATE 9

Figs 1 - 10 <u>Multioistodus?</u> <u>celox</u> sp. nov.

1, lateral view of Sa element (paratype), 5190-80, x60, GGU 227811,

2, postero-lateral view of Sa element (paratype), 5190-80, x40, GGU 227811,

3, lateral view of Sb element (paratype), 5190-82, x40, GGU 227811,

4, anterior view of Sb element (paratype), 5190-82, x40, GGU 227811,

5, lateral view of Sd element (holotype), 5190-81, x60, GGU 227811,

6, antero-lateral view of Sd element (holotype), 5190-81, x40, GGU 227811,

7, inner lateral view of Sc element (paratype), 5190-83, x40, GGU 227811,

8, outer lateral view of Sc element (paratype), 5190-83, x40, GGU 227811,

9, inner lateral view of M element (paratype), 5190-84, x40, GGU 227811,

10, outer lateral view of M element (paratype), 5190-84, x40, GGU 227811.

Figs 11 - 20 <u>Multioistodus?</u> <u>compressus</u> Harris and Harris

11, postero-lateral view of Sa element, 5192-90, x40, GGU 227821,

12, opposite postero-lateral view of Sa element, 5192-90, x40, GGU 227821,

13, lateral view of Sb element, 5192-91, x60, GGU 227821,

14, postero-lateral view of Sb element, 5192-91, x60, GGU 227821,

15, lateral view of Sd element, 5347-90, x60, GGU 227821,

16, opposite lateral view of Sd element, 5347-90, x60, GGU 227821,

17, inner lateral view of Sc element, 5192-92, x40, GGU 227821,

18, outer lateral view of Sc element, 5192-92, x40, GGU 227821,

19, inner lateral view of M element, 5192-93, x40, GGU 227821,

20, outer lateral view of M element, 5192-93, x60, GGU 227821.

Figs 21, 22 <u>"Multioistodus"</u> sp. A.

21, lateral view, 5193-98, x100, GGU 227812,

22, lateral view, 5193-97, x60, GGU 227812.


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PLATE 10

Figs 1 - 8

Oepikodus communis (Ethington and Clark)

1, outer lateral view of P element, 4892-34, x100, GGU 240015,

2, inner lateral view of M element, 4893-36, x60, GGU 240015,

3, inner lateral view of M element, 4894-36, x60, GGU 240006,

4, outer lateral view of P element, 4736-29, x60, GGU 240006,

5, lateral view of Sa element, 4894-34, x60, GGU 240006,

6, lateral view of Sb element, 4894-35, x60, GGU 240006,

7, opposite lateral view of Sb element, 4894-35, x60, GGU 240006,

8, lateral view of Sc element, 4892-35, x60, GGU 240015.

Figs 9 - 15

Oepikodus? marathonensis (Bradshaw)

9, inner lateral view of P element, 5275-60, x60, GGU 274944,

10, inner lateral view of P element, 4893-38, x60, GGU 240006,

11, inner lateral view of M element, 5275-62, x60, GGU 274944,

12, lateral view of Sa element, 5275-63, x60, GGU 274944,

13, lateral view of Sb element, 4737-35, x60, GGU 240007,

14, lateral view of Sc element, 5275-64, x60, GGU 274944,

15, lateral view of Sc element, 5276-65, x60, GGU 274945.

Fig. 16

Oepikodus sp. A.

16, lateral view of Sa element, 5345-83, x60, GGU 240014.

Fig. 17

Oepikodus sp. B.

17, lateral view, 5276-68, x60, GGU 274952.

Figs 18, 19

Oistodus? angulatus Bradshaw

18, inner lateral view, 5300-38, x60, GGU 239872,

19, inner lateral view, 5300-39, x60, GGU 239895.

Figs 20, 21

Oistodus bransoni Ethington and Clark

20, inner lateral view, 5276-69, x60, GGU 274945,

21, outer lateral view, 5276-69, x60, GGU 274945.

Fig. 22

"Oistodus" triangularis Furnish

22, lateral view, 5277-70, x60, GGU 239962.

Fig. 23

"Oistodus" sp. nov. A.

23, inner lateral view, 5277-72, x60, GGU 240014.

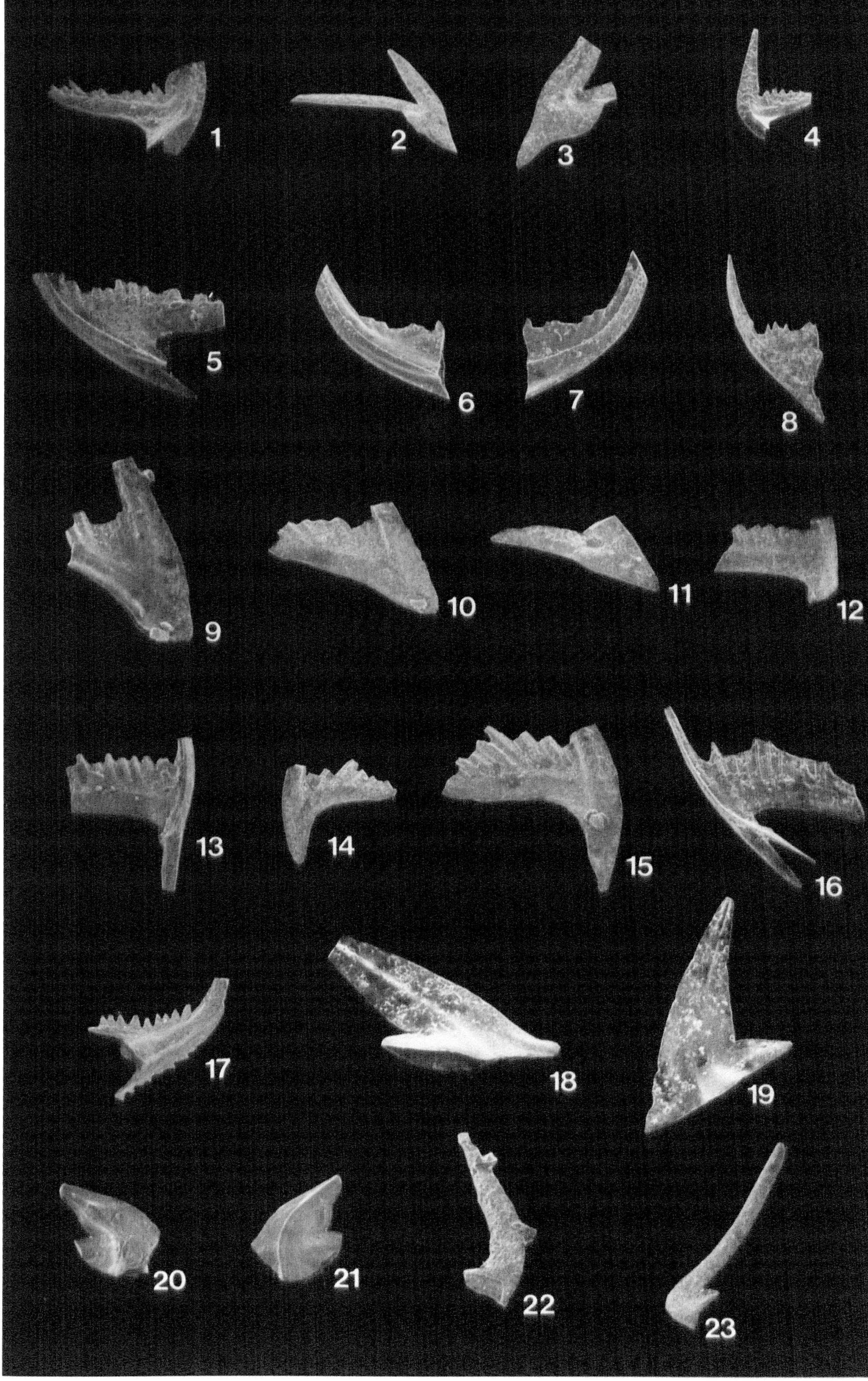
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PLATE 11

Figs 1 - 9 — Oneotodus costatus Ethington and Brand

1, lateral view, 5278-77, x40, GGU 274958,

2, lateral view, 5278-75, x60, GGU 274958,

3, lateral view, 5277-74, x60, GGU 274959,

4, lateral view, 5278-76, x60, GGU 274958,

5, lateral view, 5277-73, x60, GGU 239968,

6, lateral view, 5278-78, x100, GGU 274944,

7, upper view, 5278-78, x100, GGU 274944,

8, lateral view, 5279-79, x100, GGU 274944,

9, basal view, 5278-75, x60, GGU 274958.

Fig. 10 — "Oneotodus" mitra Abaimova

10, posterior view, 5279-80, x60, GGU 226394.

Figs 11, 12 — Oneotodus sp. A.

11, lateral view, 5279-81, x60, GGU 239985,

12, upper view, 5279-81, x40, GGU 239985.

Figs 13 - 16 — Oulodus? sp. nov. A.

13, inner lateral view of Pa element, 5303-9, x60, GGU 239901,

14, inner lateral view of Pb element, 5303-10, x60, GGU 239901,

15, posterior view of Sb element, 5303-12, x60, GGU 239901,

16, lateral view of Sc element, 5303-11, x60, GGU 239901.

Figs 17 - 23 — Panderodus aff. P. panderi (Stauffer)

17, inner lateral view of costate element, 5399-58, x60, GGU 239898,

18, inner lateral view of costate element, 5397-48, x60, GGU 239872,

19, inner lateral view of costate element with regenerated cusp, 5398-52, x40, GGU 239871,

20, outer lateral view of costate element, 5397-50, x60, GGU 239872,

21, outer lateral view of costate element, 5398-53, x100, GGU 239871,

22, inner lateral view of compressed element, 5397-47, x60, GGU 239872,

23, outer lateral view of compressed element, 5396-46, x60, GGU 239872.

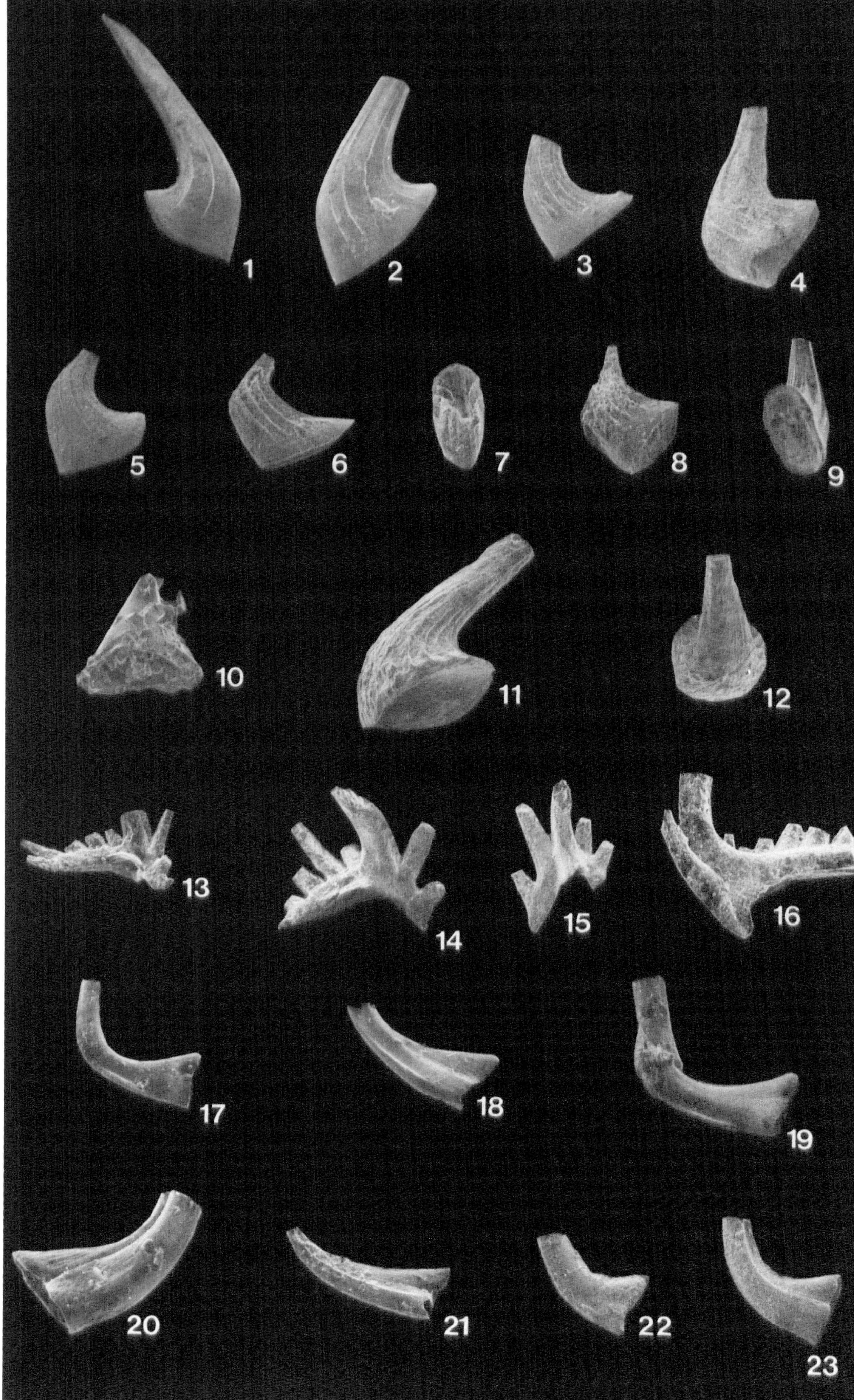
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PLATE 12

Figs 1 - 11 Paraprioniodus costatus (Mound)

1, outer lateral view of juvenile Pa element, 5169-2, x60, GGU 227845,

2, oblique upper view of mature Pa element, 4637-9, x40, GGU 227846,

3, outer lateral view of Pa element, 4731-42, x40, GGU 239821,

4, inner lateral view of Pb element, 4620-11, x40, GGU 227846,

5, lateral view of Sc element, 5170-7, x40, GGU 227846,

6, lateral view of Sc element, 4620-12, x40, GGU 227846,

7, outer lateral view of Sb/Sd element, 4731-41, x40, GGU 239821,

8, posterior view of Sa element, 5170-8, x40, GGU 271659,

9, inner lateral view of M element, 5170-6, x60, GGU 227846,

10, inner lateral view of M element, 5169-4, x60, GGU 227812,

11, inner lateral view of Pb element with serrate anterior margin, 5170-9, x60, GGU 271662.

Figs 12 - 17, 24 Phragmodus flexuosus Moskalenko

12, inner lateral view of P element, 5179-3, x40 GGU 227839,

13, inner lateral view of M element, 5179-4, x40, GGU 274922,

14, lateral view of Sa element (even denticulation), 5179-5, x40, GGU 227839,

15, lateral view of Sa element (phragmodiform denticulation), 5174-77, x60, GGU 274922,

16, opposite lateral view of Sa element (phragmodiform denticulation), 5174-77, x60, GGU 274922,

17, lateral view of Sc element, 5174-80, x60, GGU 227839,

24, outer lateral view of Sb element, 5174-78, x60, GGU 274922.

Figs 18, 19 Phragmodus sp. nov. A.

18, lateral view of M element, 5175-81, x60, GGU 227854,

19, lateral view of Sc element, 5175-82, x60, GGU 227854.

Figs 20 - 23 Plectodina? sp. A.

20, lateral view of Pa element, 5304-13, x100, GGU 227837,

21, lateral view of Pa element, 5304-16, x100, GGU 227837,

22, posterior view of Sb element, 5304-14, x100, GGU 227837,

23, lateral view of Sc element, 5304-15, x60, GGU 227837.

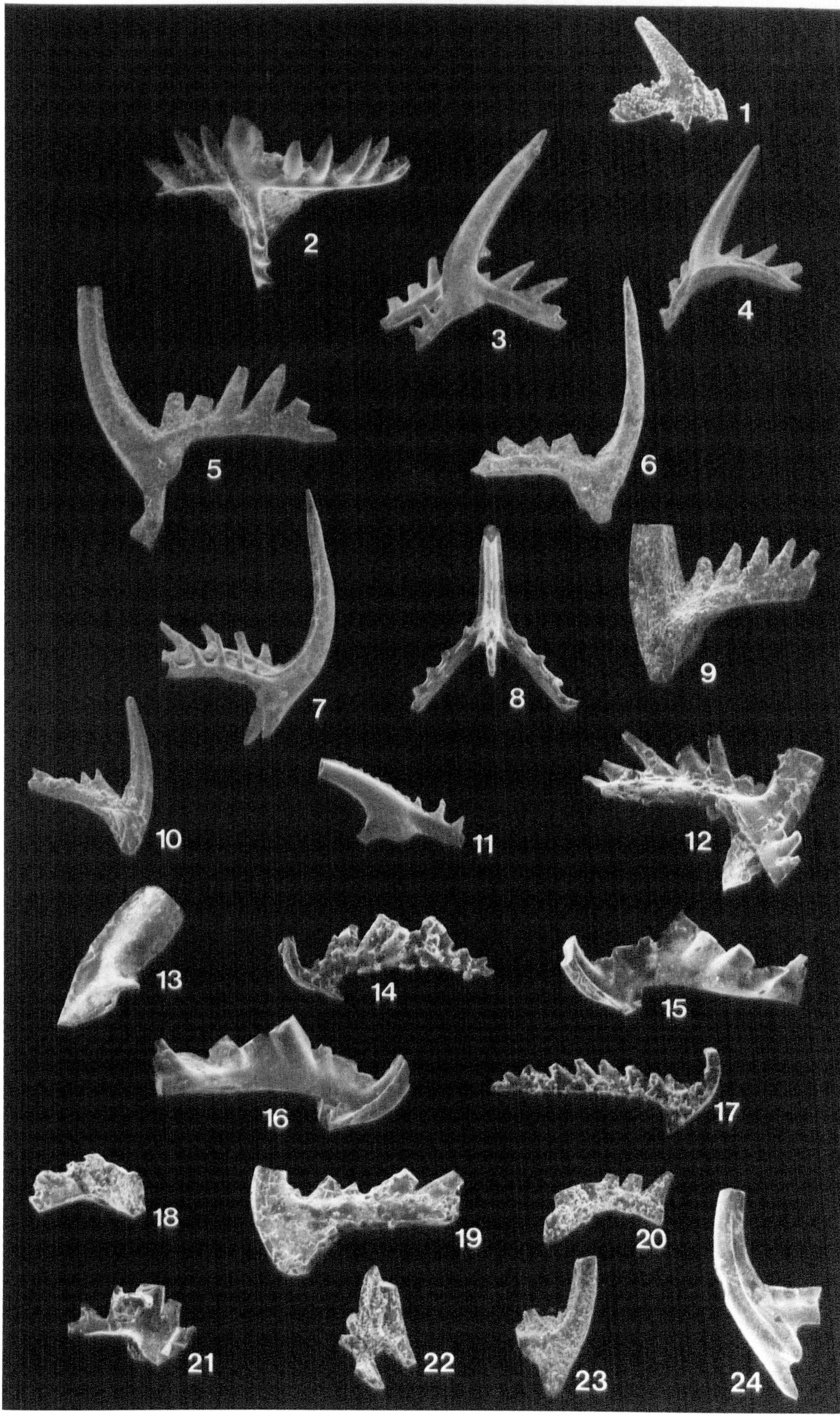
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PLATE 13

Figs 1 - 3
Protopanderodus elongatus Serpagli

1, lateral view, 5280-34, x60, GGU 240015,
2, lateral view, 5279-82, x100, GGU 240015,
3, lateral view, 5279-82, x100, GGU 240015.

Figs 4 - 12
Protopanderodus gradatus Serpagli

4, outer lateral view of scolopodiform element, 5280-37, x40, GGU 240014,
5, inner lateral view of intermediate element, 5280-38, x40, GGU 240014,
6, outer lateral view of intermediate element, 5280-38, x40, GGU 240014,
7, inner lateral view of intermediate element, 5280-36, x40, GGU 240014,
8, inner lateral view of intermediate element, 5280-36, x40, GGU 240014,
9, inner lateral view of scandodiform element, 5281-40, x60, GGU 240015,
10, outer lateral view of scandodiform element, 5281-40, x60, GGU 240015,
11, inner lateral view of short-based element, 5281-39, x60, GGU 240014,
12, outer lateral view of short-based element, 5281-39, x60, GGU 240014.

Figs 13 - 14
Protopanderodus leonardii Serpagli

13, lateral view, 5281-42, x60, GGU 240014,
14, lateral view, 5281-43, x60, GGU 240015.

Fig. 15
Protopanderodus cf. P. gradatus Serpagli

15, inner lateral view, 5281-41, x60, GGU 226397.

Fig. 16
Protoprioniodus aranda Cooper

16, inner lateral view of M element, 5195-98, x60, GGU 274938.

Figs 17 - 23
Protoprioniodus papiliosus (van Wamel)

17, inner lateral view of oistodiform element, 5283-50, x100, GGU 240015,
18, outer lateral view of oistodiform element, 5283-50, x100, GGU 240015,
19, inner lateral view of oistodiform element, 5282-45, x100, GGU 240014,
20, lateral view of ramiform element, 5282-48, x60, GGU 240006,
21, lateral view of ramiform element, 5283-49, x100, GGU 240015,
22, lateral view of ramiform element, 5282-44, x100, GGU 274944,
23, posterior view of ramiform element, 5282-44, x100, GGU 274944.

Fig. 24
Pseuooneotodus sp.

24, upper view, 5300-40, x60, GGU 239857.

Figs 25 - 38
Pteracontiodus armillatus sp. nov.

25, posterior view of Sa element (paratype),5283-52, x40, GGU 274945,
26, posterior view of Sa element (paratype),5283-51, x40, GGU 274959,
27, inner lateral view of Sb element (paratype), 5283-53, x40, GGU 274959,
28, inner lateral view of Sb element (paratype), 5284-54, x40, GGU 227806,
29, outer lateral view of Sb element (paratype), 5284-54, x40, GGU 227806,
30, inner lateral view of Sc element (paratype), 5284-55, x40, GGU 227847,
31, outer lateral view of Sc element (paratype), 5284-55, x40, GGU 227847,
32, outer lateral view of Sd element (holotype), 5284-57, x40, GGU 274959,
33, inner lateral view of Sd element (holotype), 5284-57, x40, GGU 274959,
34, inner lateral view of M element (paratype), 5285-60, x40, GGU 274945,
35, inner lateral view of M element (paratype), 5285-59, x60, GGU 274945,
36, outer lateral view of M element (paratype), 5285-59, x60, GGU 274945,
37, inner lateral view of M element (paratype), 5285-61, x40, GGU 274945,
38, outer lateral view of M element (paratype), 5285-61, x40, GGU 274945,

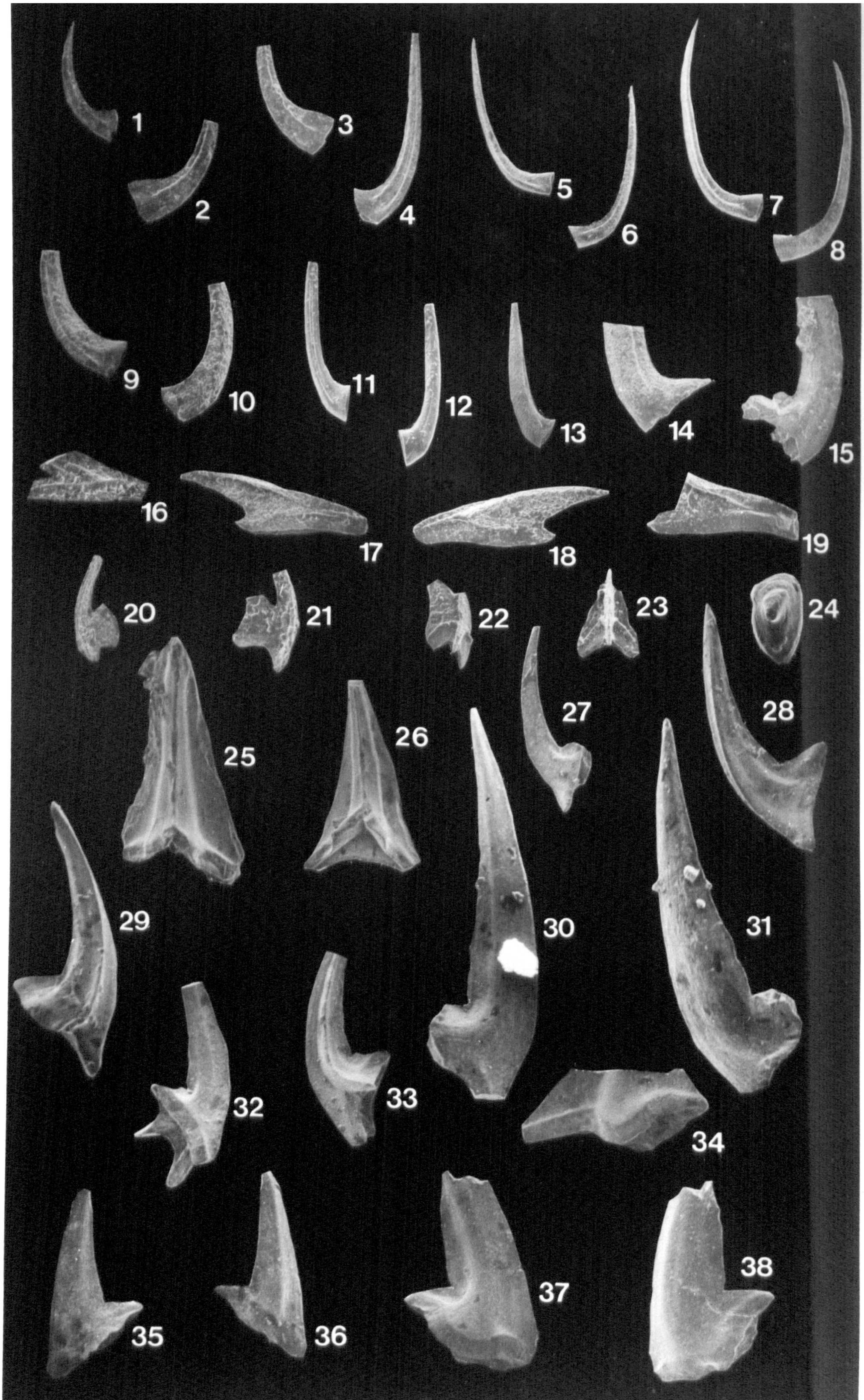
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PLATE 14

Figs 1 - 4

Pteracontiodus cryptodens (Mound)

1, posterior view of Sa element, 5285-62, x40, GGU 240034,

2, outer lateral view of Sb element, 5285-63, x60, GGU 240033,

3, lateral view of Sc element, 5285-64, x40, GGU 240028,

4, lateral view of Sd element, 5286-65, x40, GGU 240033.

Figs 5 - 8

Pteracontiodus? sp. A.

5, lateral view, 5196-0, x100, GGU 274938,

6, opposite lateral view, 5196-0, x100, GGU 274938,

7, lateral view, 5196-1, x100, GGU 274938,

8, opposite lateral view, 5196-1, x100, GGU 274938.

Fig. 9

Pygodus anserinus Lamont and Lindström

9, upper view of pygodiform element, 4733-11, x100, GGU 239898.

Fig. 10

Pygodus sp.

10, lateral view of haddingodiform element, 4734-12, x100, GGU 239872.

Figs 11, 12

?Reutterodus andinus Serpagli

11, inner lateral view, 4736-31, x40, GGU 240018,

12, outer lateral view, 4736-31, x40, GGU 240018.

Figs 13 - 21

Scalpellodus? narvhalensis sp. nov.

13, lateral view of q element, 5288-96, x60, GGU 240014,

14, opposite lateral view of q element, 5288-96, x60, GGU 240014,

15, lateral view of p/q element, 5288-97, x60, GGU 240014,

16, lateral view of p/q element, 5287-93, x60, GGU 240014,

17, lateral view of p element, 5287-94, x60, GGU 240014,

18, opposite lateral view of p element, 5287-94, x60, GGU 240014,

19, inner lateral view of r element, 5286-68, x60, GGU 240014,

20, outer lateral view of r element, 5286-68, x60, GGU 240014,

21, inner lateral view of r element, 5287-92, x60, GGU 240014.

Figs 22, 23

Scalpellodus? sp. A.

22, inner lateral view, 5288-98, x60, GGU 240009,

23, outer lateral view, 5288-98, x60, GGU 240009.

Figs 24, 25

Scandodus furnishi sensu Ethington and Clark

24, inner lateral view, 5288-99, x60, GGU 274959,

25, inner lateral view, 5289-1, x60, GGU 274958.

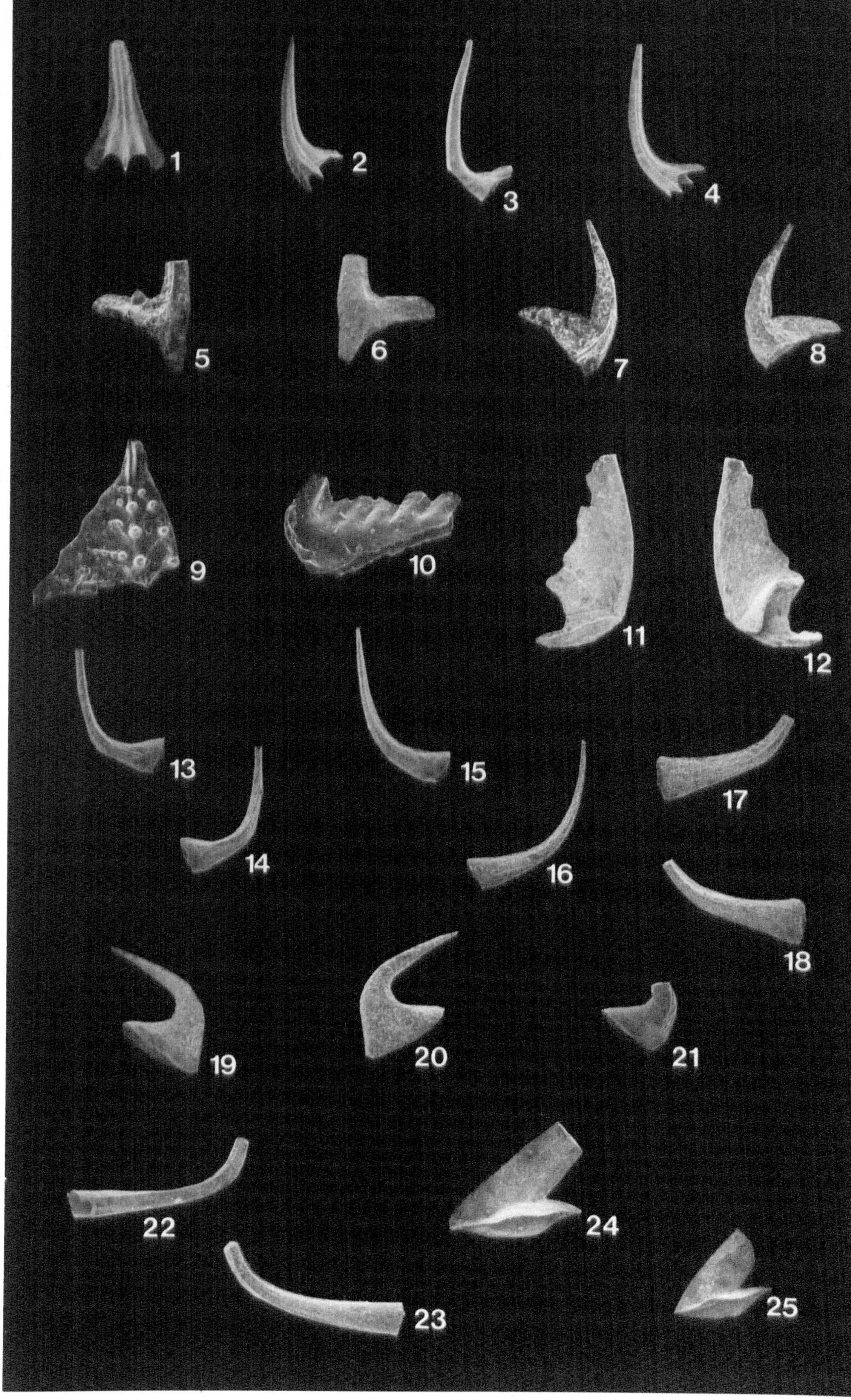

PLATE 15

Figs 1 - 8 — "Scandodus" sp. nov. A.

1, inner lateral view of p element, 5289-3, x40, GGU 239968,

2, inner lateral view of p element, 5289-4, x40, GGU 274955,

3, inner lateral view of p element, 5289-5, x40, GGU 274950,

4, inner lateral view of q element, 5290-8, x40, GGU 274955,

5, outer lateral view of q element, 5290-6, x40, GGU 239984,

6, inner lateral view of r element, 4896-4, x60, GGU 226394,

7, inner lateral view of r element, 5290-10, x40, GGU 274950,

8, outer lateral view of r element, 5290-10, x40, GGU 274950.

Fig. 9 — Scandodiform 1

9, inner lateral view, 5305-22, x40, GGU 227821.

Fig. 10 — "Scolopodus" emarginatus Barnes and Tuke

10, oblique lateral view, 5347-92, x60, GGU 274944.

Fig. 11 — "Scolopodus" filosus Ethington and Clark

11, lateral view, 5348-94, x60, GGU 274945.

Figs 12 - 17 — "Scolopodus" gracilis Ethington and Clark

12, lateral view of s element, 5291-13, x40, GGU 274944,

13, lateral view of s element, 5291-12, x40, GGU 274944,

14, oblique postero-lateral view of t element, 5292-15, x60, GGU 274944,

15, posterior view of t element, 5348-97, x60, GGU 240006,

16, posterior view of u element, 5349-99, x40, GGU 240007,

17, lateral view of u element, 5349-99, x40, GGU 240007.

Fig. 18 — Scolopodus quadratus Pander?

18, lateral view, 5349-0, x60, GGU 274957.

Fig. 19 — Scolopodus sp. A.

19, lateral view, 5292-18, x60, GGU 239968.

Fig. 20 — Semiacontiodus sp. A.

20, postero-lateral view, 5349-1, x60, GGU 239960.

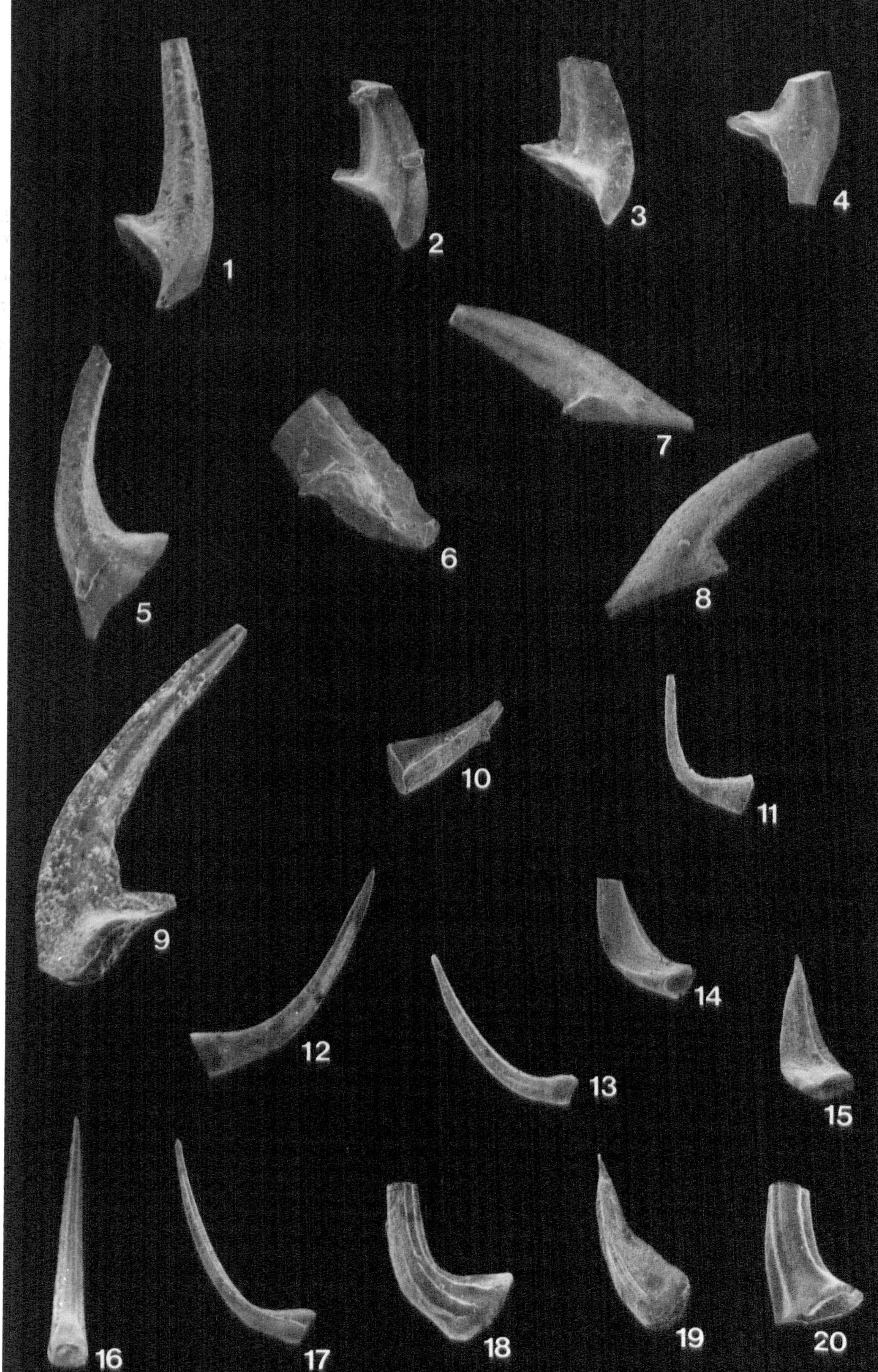
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PLATE 16

Figs 1 - 10

Sibiriodus? kalalekus sp. nov.

1, inner lateral view of scandodiform element (holotype), 5304-17, x60, GGU 227834,
2, outer lateral view of scandodiform element (holotype), 5304-17, x60, GGU 227834,
3, inner lateral view of drepanodiform element with anticusp (paratype), 5305-18, x60, GGU 227834,
4, outer lateral view of drepanodiform element with anticusp (paratype), 5305-18, x60, GGU 227834,
5, inner lateral view of drepanodiform element (paratype), 5305-19, x60, GGU 227834,
6, outer lateral view of drepanodiform element (paratype), 5305-19, x60, GGU 227834,
7, posterior lateral view of acodiform element (paratype) 5305-20, x60, GGU 227834,
8, postero-lateral view of acodiform element (paratype), 5305-20, x60, GGU 227834,
9, lateral view of trichonodelliform element (paratype), 5305-21, x60, GGU 227834,
10, opposite lateral view of trichonodelliform element (paratype), 5305-21, x60, GGU 227834.

Fig. 11

Stereoconus cf. S. circulus Moskalenko

11, lateral view, 4732-2, x60, GGU 239827.

Figs 12 - 14

Tropodus australis (Serpagli)

12, lateral view of tricostate element, 5349-2, x60, GGU 240015,
13, posterior view of quinquicostate element with serrate postero-lateral costae, 5292-19, x60, GGU 240015,
14, lateral view of serrate quinquicostate element, 5292-19, x60, GGU 240015.

Figs 15 - 25

Tropodus comptus (Branson and Mehl)

15, posterior view of tricostate element, 4895-43, x60, GGU 226394,
16, outer lateral view of tricostate element, 4895-43, x60, GGU 226394,
17, outer lateral view of tricostate element with bifid antero-lateral costa, 5293-21, x60, GGU 274945,
18, inner lateral view of tricostate element with bifid outer antero-lateral costa, 5293-21, x60, GGU 274945,
19, posterior view of quadricostate element, 4895-42, x60, GGU 226394,
20, lateral view of symmetrical quinquicostate element, 5293-23, x40, GGU 239983,
21, posterior view of symmetrical quinquicostate element, 5293-23, x40, GGU 239983,
22, outer lateral view of comptiform, 5294-6, x60, GGU 239982,
23, inner lateral view of comptiform element, 5294-6, x60, GGU 239982,
24, outer lateral view of comptiform element with supplementary costae, 5294-8, x60, GGU 274916,
25, outer lateral view of comptiform element with bifid outer antero-lateral costa, 5294-7, x60, GGU 226394.

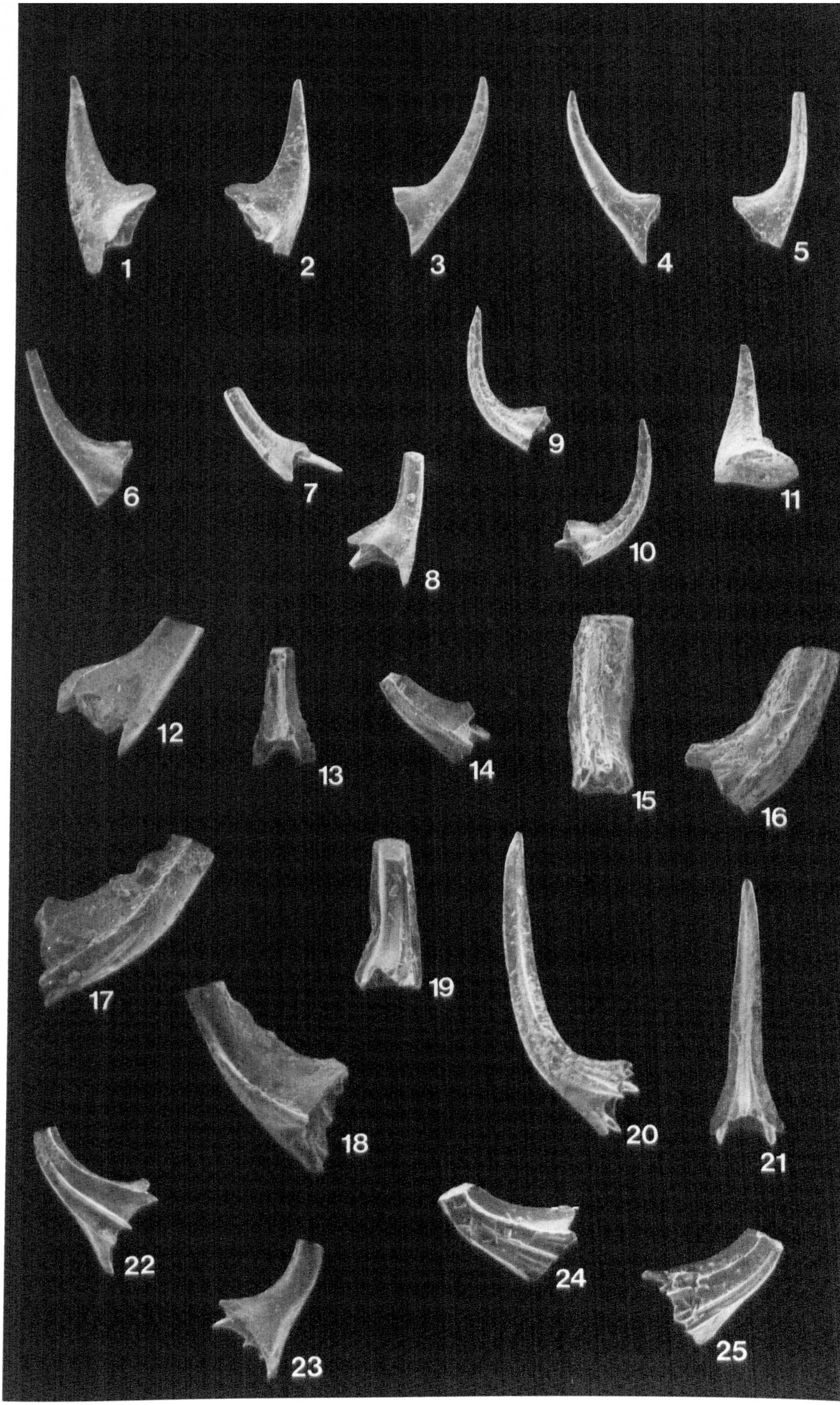
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PLATE 17

Figs 1 - 7 **Tropodus? sp. nov. A.**

1, posterior view of symmetrical element, 5294-10, x40, GGU 274945,

2, posterior view of symmetrical element, 5294-9, x40, GGU 274945,

3, lateral view of symmetrical element, 5294-9, x40, GGU 274945,

4, inner lateral view of symmetrical element, 5295-11, x60, GGU 274945,

5, inner lateral view of asymmetrical element, 5295-13, x40, GGU 274945,

6, inner lateral view of asymmetrical element, 5295-12, x60, GGU 274945,

7, outer lateral view of asymmetrical element, 5295-12, x60, GGU 274945.

Figs 8, 9 **Tropodus sp. B.**

8, inner lateral view, 5295-14, x60, GGU 274945,

9, outer lateral view, 5295-14, x60, GGU 274945.

Figs 10 - 13 **Trigonodus? sinuosus** (Mound)

10, lateral view of Sa element, 5175-83, x40, GGU 239827,

11, inner lateral view of Sb element, 5175-84, x60, GGU 239823,

12, inner lateral view of Sc element, 5175-85, x40, GGU 227845,

13, lateral view of Sd element, 5175-86, x40, GGU 227821.

Figs 14 - 16 **Ulrichodina abnormalis** (Branson and Mehl)

14, lateral view, 4896-6, x60, GGU 226394,

15, lateral view, 5296-17, x60, GGU 226394.

16, lateral view, 5296-16, x60, GGU 226394.

Figs 17, 18 **Ulrichodina wisconsinensis** Furnish

17, lateral view, 5296-19, x60, GGU 274916,

18, lateral view, 5296-20, x60, GGU 274945.

Fig. 19 **Ulrichodina sp. nov. A.**

19, lateral view, 5297-21, x60, GGU 274947.

Fig. 20 **Ulrichodina sp. nov. B.**

20, lateral view, 5297-22, x60, GGU 274944.

Fig. 21 **Ulrichodina sp. C.**

21, lateral view, 5297-23, x60, GGU 274916.

Figs 22, 23 **Utahconus? bassleri** (Furnish)

22, lateral view, 5297-24, x60, GGU 239960,

23, lateral view, 5297-25, x40, GGU 239960.

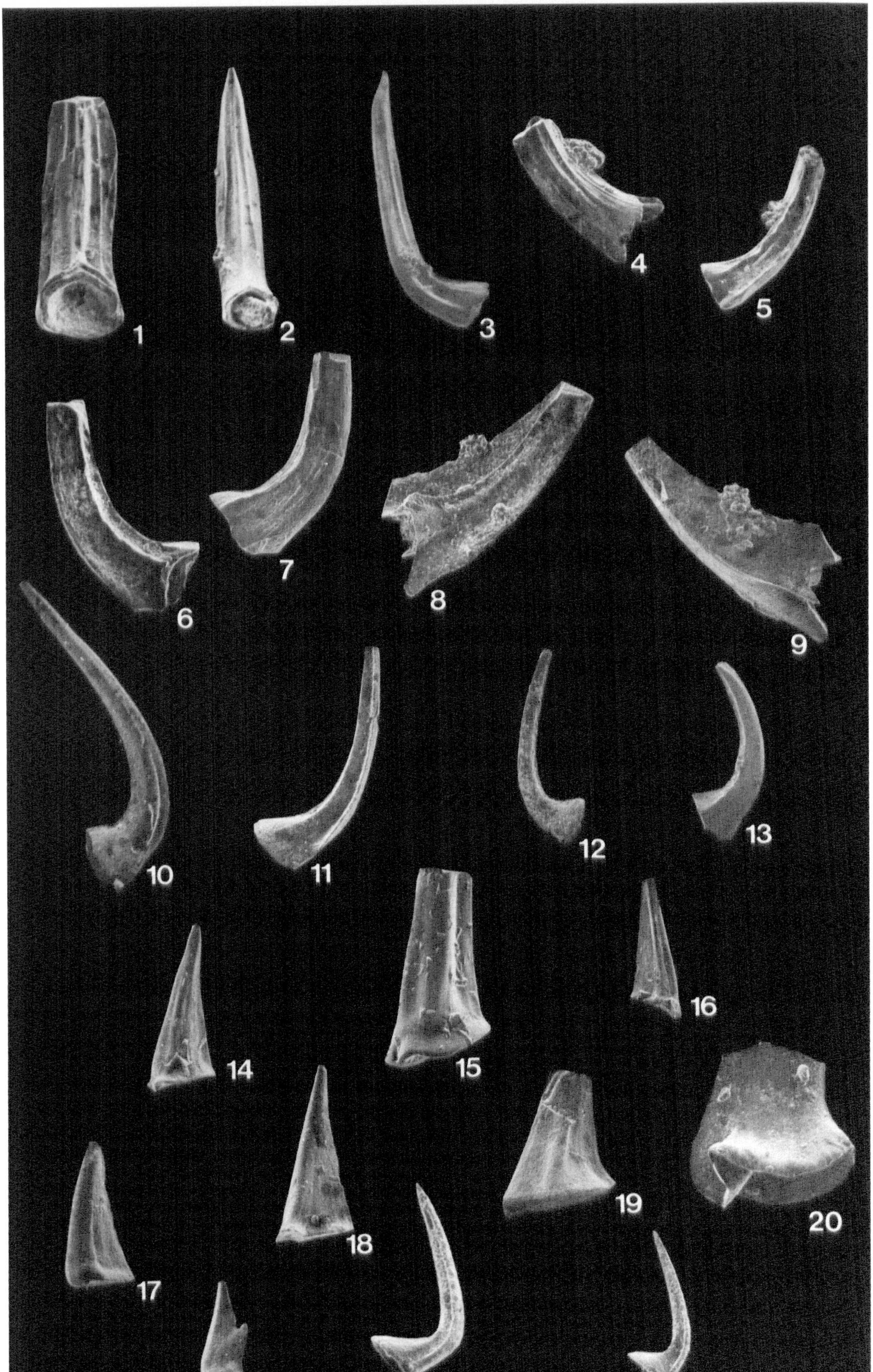
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PLATE 18

Figs 1 - 6

Wandelia fuscina gen. et sp. nov.

1, posterior view of Sa element (holotype), 4731-1, x60, GGU 239818,
2, posterior view of Sa element (paratype), 5189-76, x60, GGU 239818,
3, anterior view of Sa element (paratype), 5189-76, x60, GGU 239818,
4, postero-lateral view of Sb element (paratype), 4731-43, x60, GGU 239818,
5, antero-lateral view of Sb element (paratype), 4731-43, x60 GGU 239818,
6, inner lateral view of Sc element (paratype), 5189-77, x60, GGU 239818.

Figs 7 - 11

Wandelia? sp. nov. A.

7, posterior view of Sa element, 5191-85, x60, GGU 274921,
8, posterior view of Sb element, 5191-86, x60, GGU 274921,
9, posterior view of Sb element, 5191-87, x60, GGU 274921,
10, anterior view of Sb element, 5191-87, x60, GGU 274921,
11, lateral view of Sc element, 5191-88, x60, GGU 274921.

Figs 12 - 14

Weberina guyi gen. et sp. nov.

12, upper view (paratype), 5298-30, x60, GGU 240006,
13, lateral view (holotype), 4734-15, x100, GGU 240006,
14, lower view (paratype), 5298-30, x60, GGU 240006.

Figs 15 - 18

Weberina candidisphaera gen. et sp. nov.

15, upper view (paratype), 5298-26, x150, GGU 240014,
16, upper view (paratype), 5298-27, x150, GGU 240014,
17, lower view (paratype), 5298-28, x150, GGU 240014,
18, lateral view (holotype), 5298-29, x150, GGU 240014.

Fig. 19

Weberina sp. A.

19, upper view, 5299-34, x60, GGU 274953.

Figs 20 - 23

Gen. nov. A. sp. nov. A.

20, lateral view of Coniform A element, 5306-25, x60, GGU 239977,
21, lateral view of Coniform B element, 5306-26, x60, GGU 240009,
22, lateral view of Pastinate A element, 5306-27, x60, GGU 239982,
23, lateral view of Pastinate B element, 5306-28, x60, GGU 239970.

Figs 24, 25

Gen. nov. A. sp. nov. B.

24, lateral view of Pastinate A element, 5307-29, x60, GGU 226394,
25, lateral view of Pastinate B element, 4894-38, x60, GGU 226394.

Fig. 26

Gen. nov. B.

26, lateral view, 5177-96, x60, GGU 239849.

Fig. 27, 28

Gen. nov. C.

27, inner lateral view,5302-7, x60, GGU 239850,
28, outer lateral view,5302-7, x60, GGU 239850.

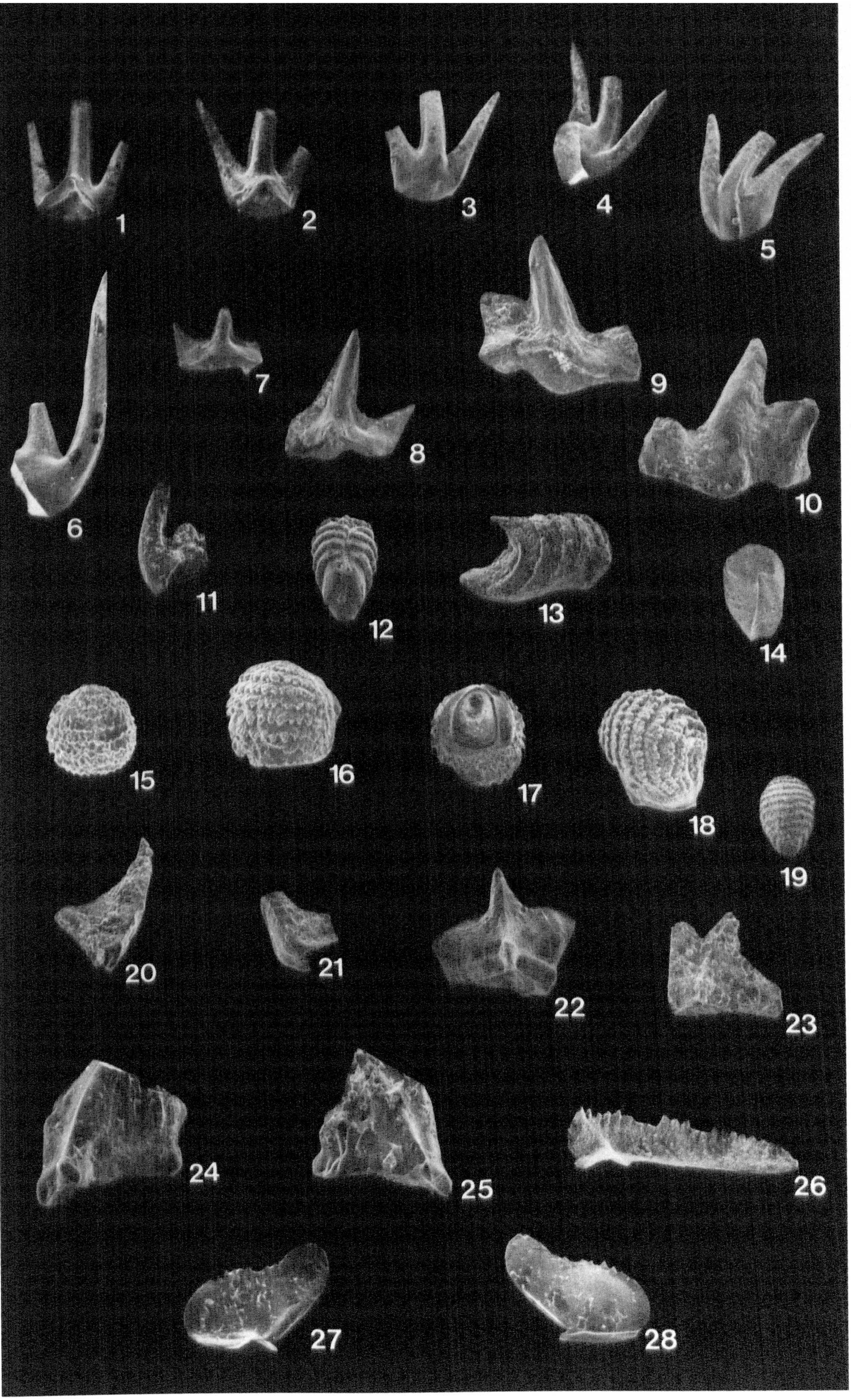
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PLATE 19

Figs 1 - 4 *Oepikodus communis* (Ethington and Clark)

1, lateral view of cluster (stereo-pair), 5019-35, x120, GGU 239755,

2, opposite lateral view of cluster (stereo-pair), 5019-35, x120, GGU 239755,

3, oblique view of cluster, 5019-35, x120, GGU 239755,

4, lateral view of cluster (stereo-pair), 5018-30, x300, GGU 240006.

Stereo-pairs photographed with 6° separation.

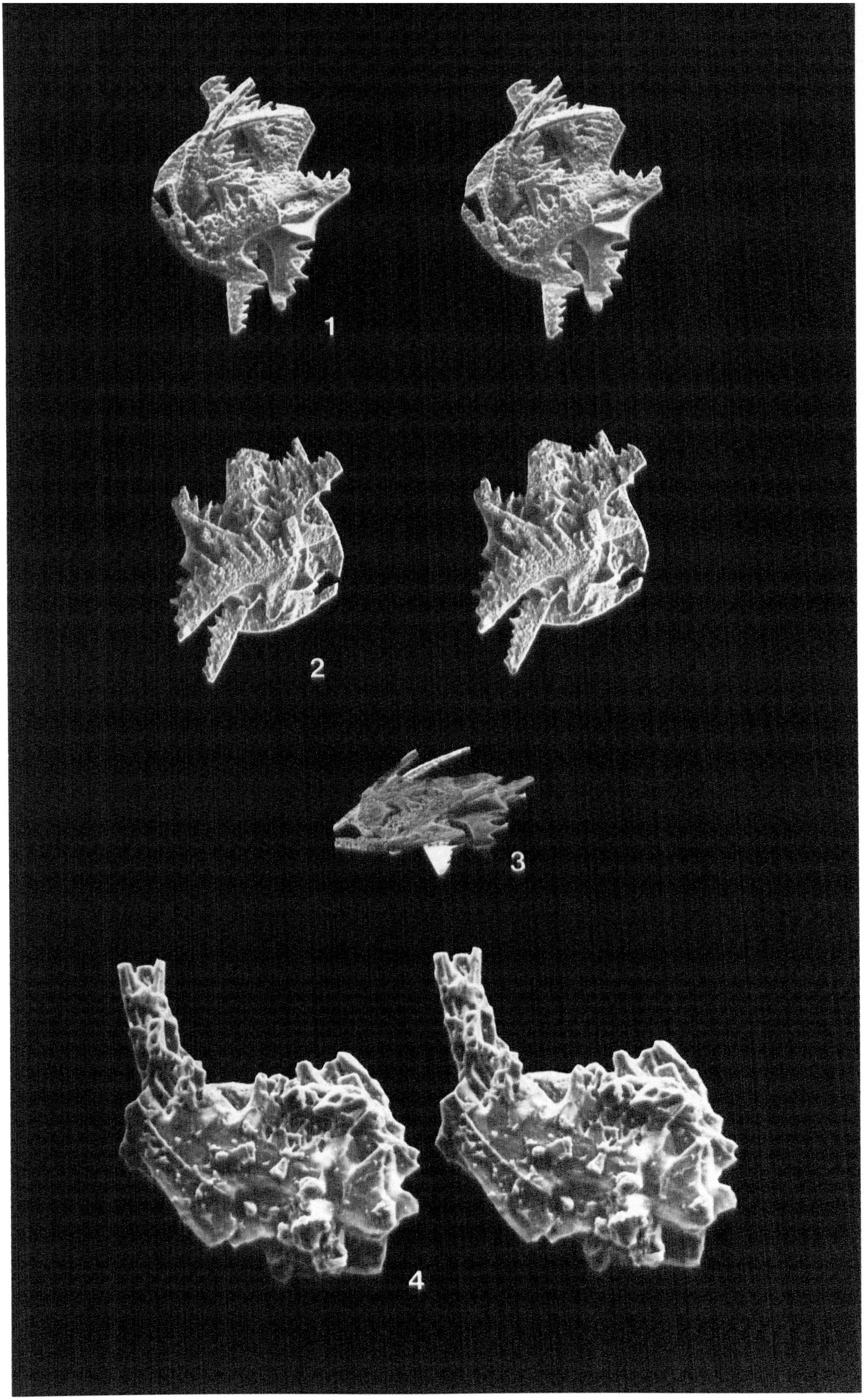
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PLATE 20

Figs 1 - 4 "Scolopodus" gracilis Ethington and Clark

1, lateral view of cluster (stereo-pair), 5017-24, x60, GGU 239743,

2, lateral view of cluster (stereo-pair), 5017-26, x120, GGU 270024,

3, postero-lateral view of cluster (stereo-pair), 5019-33, x60, GGU 239753,

4, posterior-view of cluster, 5019-33, x60, GGU 239753.

Stereo-pairs photographed with 6° separation

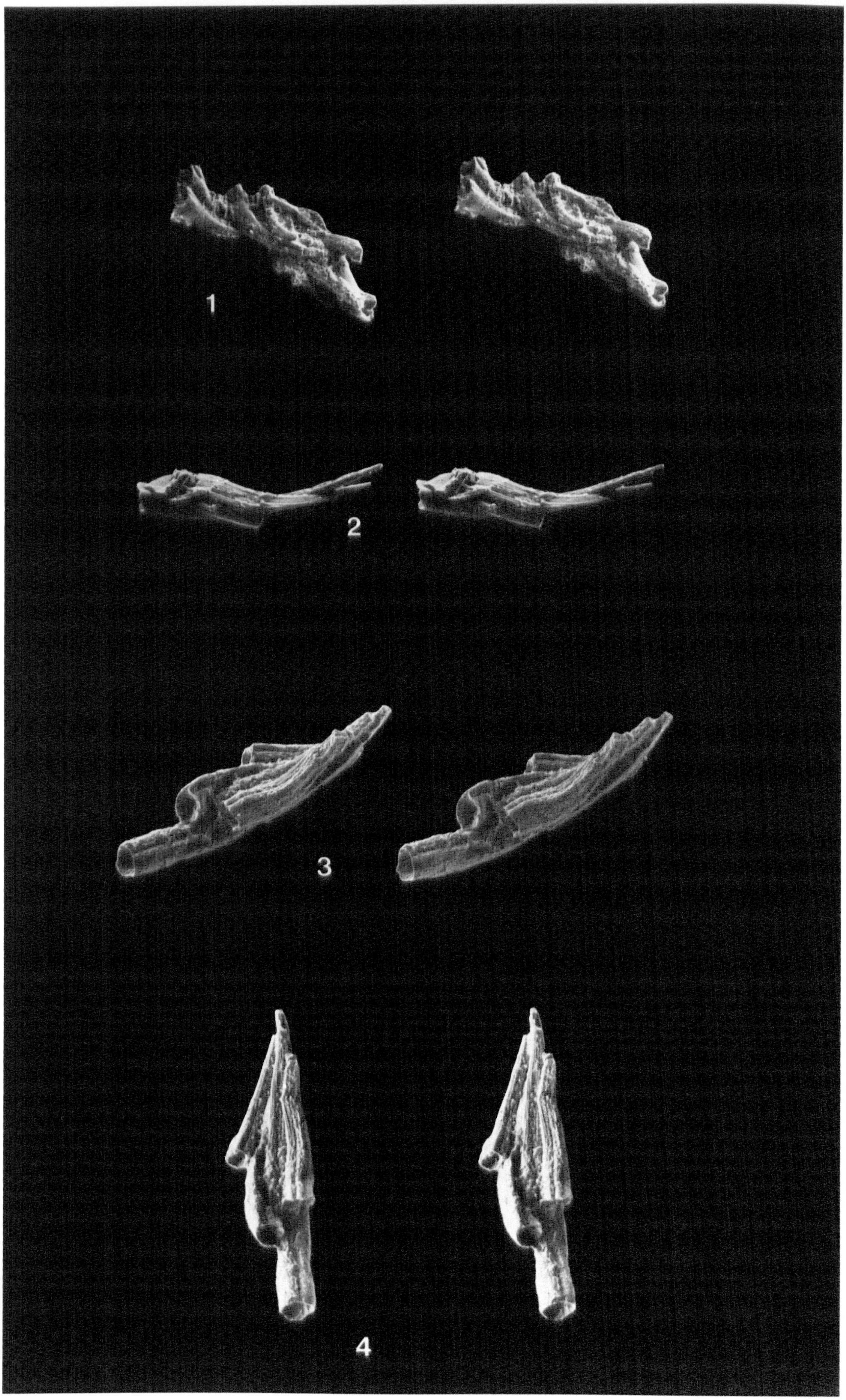
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PLATE 21

Figs 1, 2 — *Drepanoistodus suberectus* (Branson and Mehl)

1, lateral view of cluster (stereo-pair), 5197-8, x80, GGU 239857,

2, opposite lateral view of cluster (stereo-pair), 5197-8, x80, GGU 239857.

Figs 3 - 5 — *Panderodus* aff. *P. panderi* (Stauffer)

3, lateral view of cluster (stereo-pair) 5309-49, x120, GGU 239863,

4, lateral view of cluster (stereo-pair), 5197-12, x120, GGU 239866,

5, posterior view of cluster (stereo-pair), 5197-12, x120, GGU 239866.

Stereo-pairs photographed with 6^{o} separation

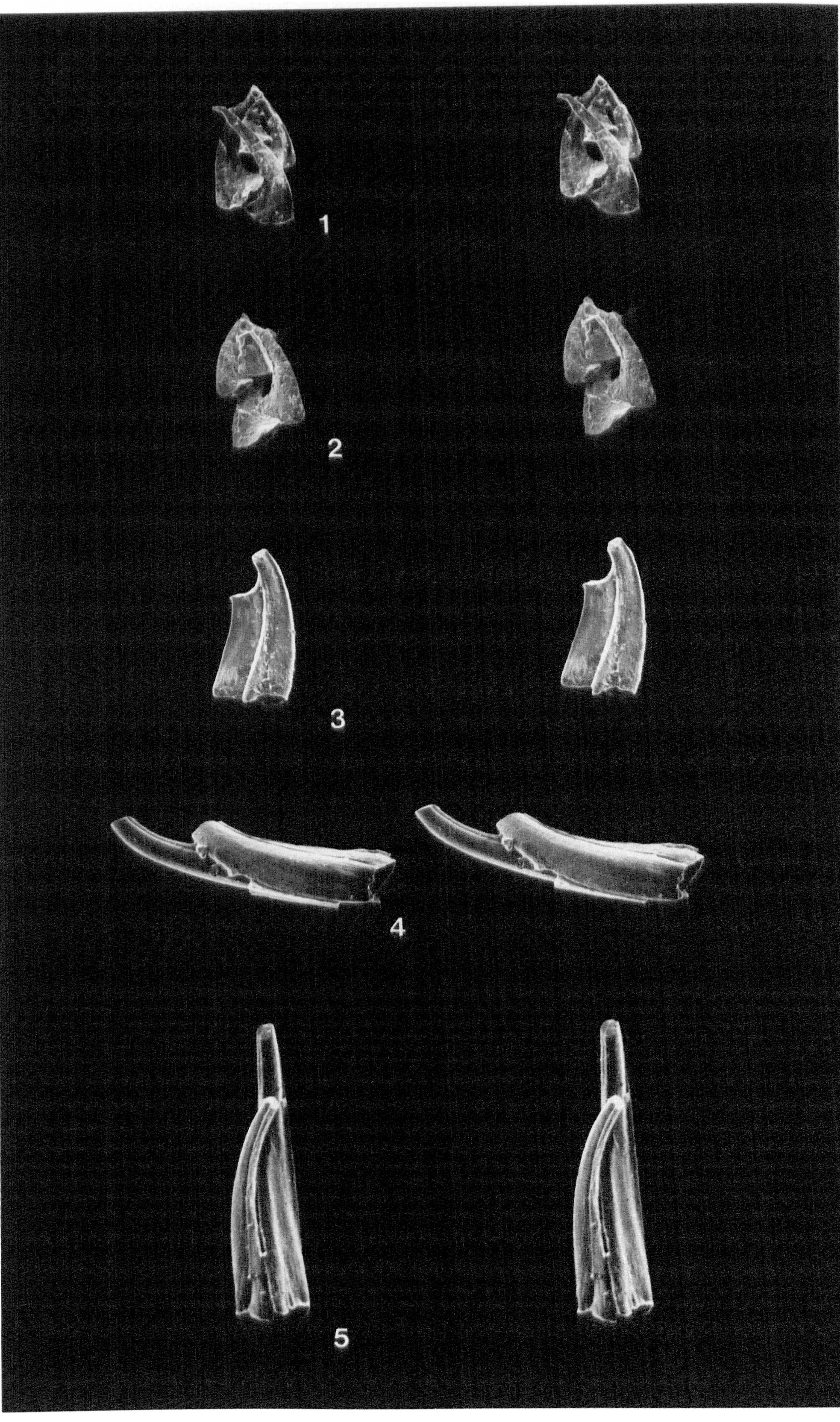
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PLATE 22

Figs 1 - 4 *Panderodus* aff. *P. panderi* (Stauffer)

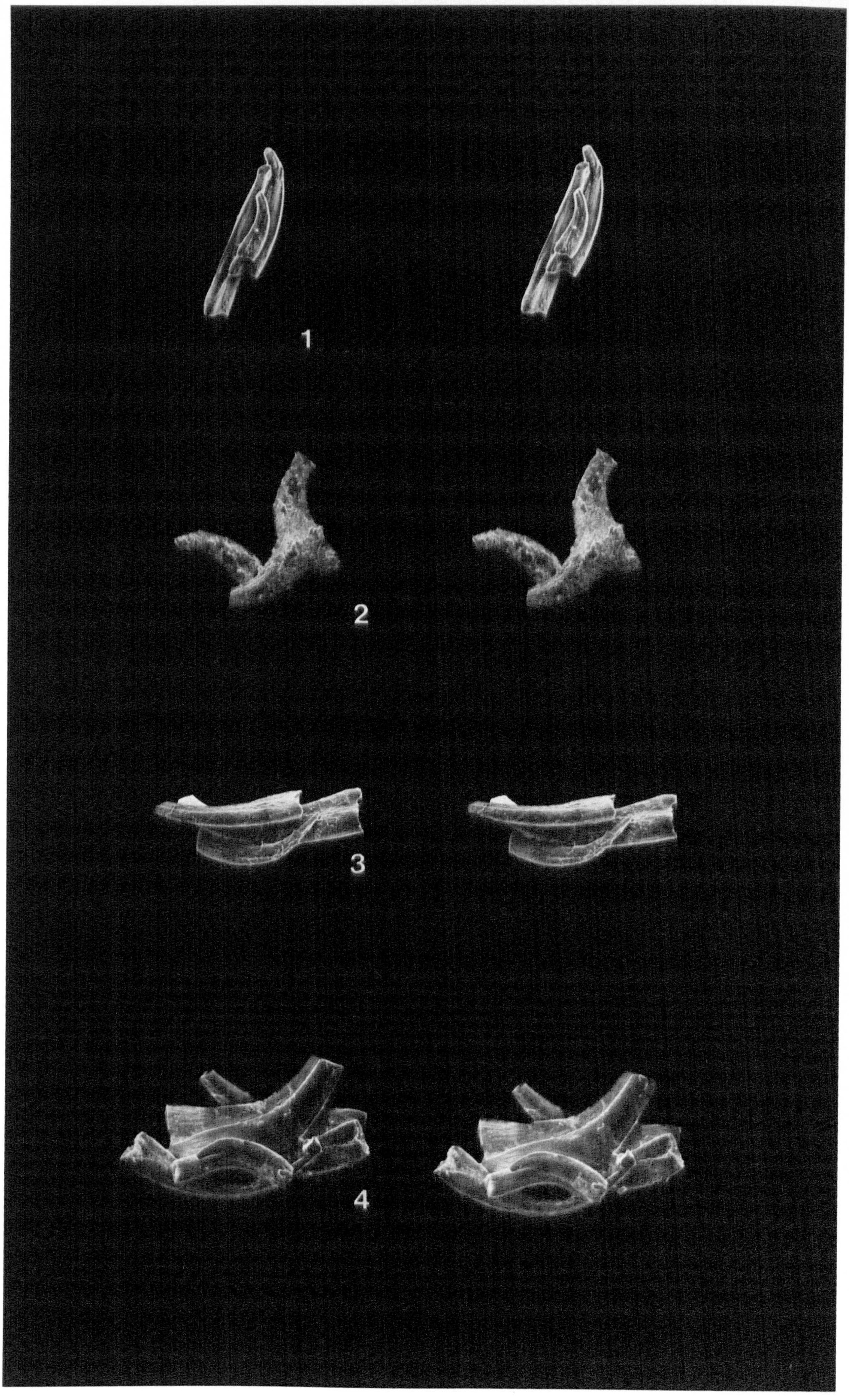
1, posterior view of cluster (stereo-pair), 5309 - 51, x80, GGU 239859,

2, lateral view of cluster (stereo-pair), 5197-9. x60, GGU 239859,

3, lateral view of cluster (stereo-pair), 5198-16, x120, GGU 239877,

4, lateral view of cluster (stereo-pair), 5198-14, x140, GGU 239868.

Stereo-pairs photographed with 6^{o} separation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Aerial Photograph Descriptions and key

Fig. 3.4 Oblique aerial photograph showing positions and geological context of sections JSP 780711-1 and JSP 780711-2, east side of Hans Tavsens Iskappe, western Peary Land.

Fig. 3.5 Aerial photograph showing position and geological context of section JEM 790701-1, Børglum Elv, central Peary Land.

Fig. 3.6 Oblique aerial photograph showing position and geological context of sections JEM 790627-1 (profiles 1-3) and JEM 790627-2 (profile 4), Børglum Elv, central Peary Land.

Fig. 3.7 Oblique aerial photograph showing positions and geological context of sections JSP 800702-1 (profile A), JSP 800704-2 (profile B), JSP 800630-5 (locality C) and JSP 800630-6 (locality C), Danmark Fjord, Kronprins Christian Land.

Fig. 3.11 Aerial photograph showing position of section PF 770824-1, Ella Ø.

Fig. 3.12 Aerial photograph showing position of section PF 770713-1, Albert Heim Bjerge.

Key

BR	Børglum River Formation
O(U-N)	New, un-named Ordovician formation
WV	Wandel Valley Formation
KH	Kap Holbaek Formation
TIG	Tavsens Iskappe Group
BFG	Bronlund Fjord Group


Bure Iskappe
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WV
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WV
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Hans Tavsens Iskappe
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WV
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BFG
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Fig. 3.4

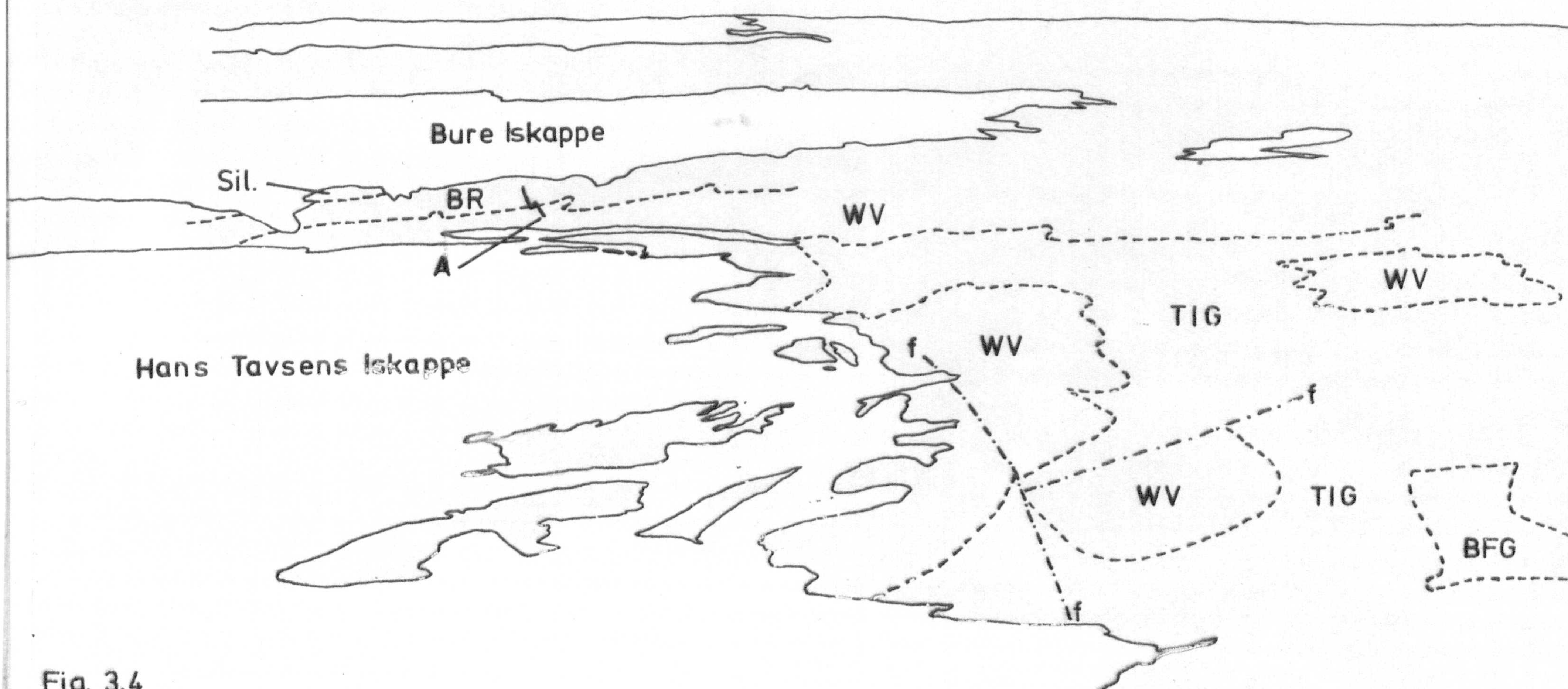
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Fig. 3.4


Fig. 3.5
Børglum Elv
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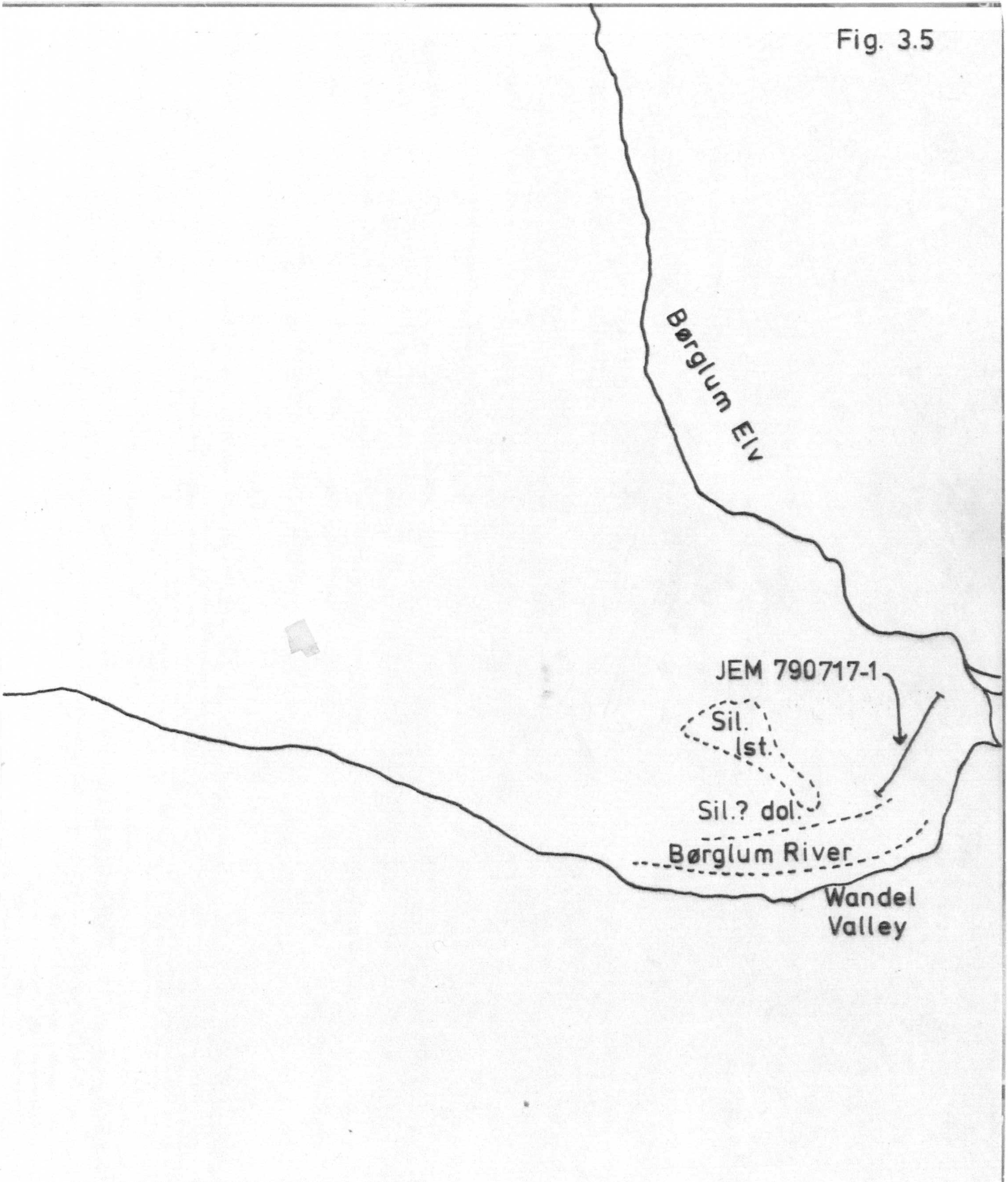
Børglum River
Wandel
Valley

Fig. 3.5



Børglum Elv
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Børglum River
Wandel
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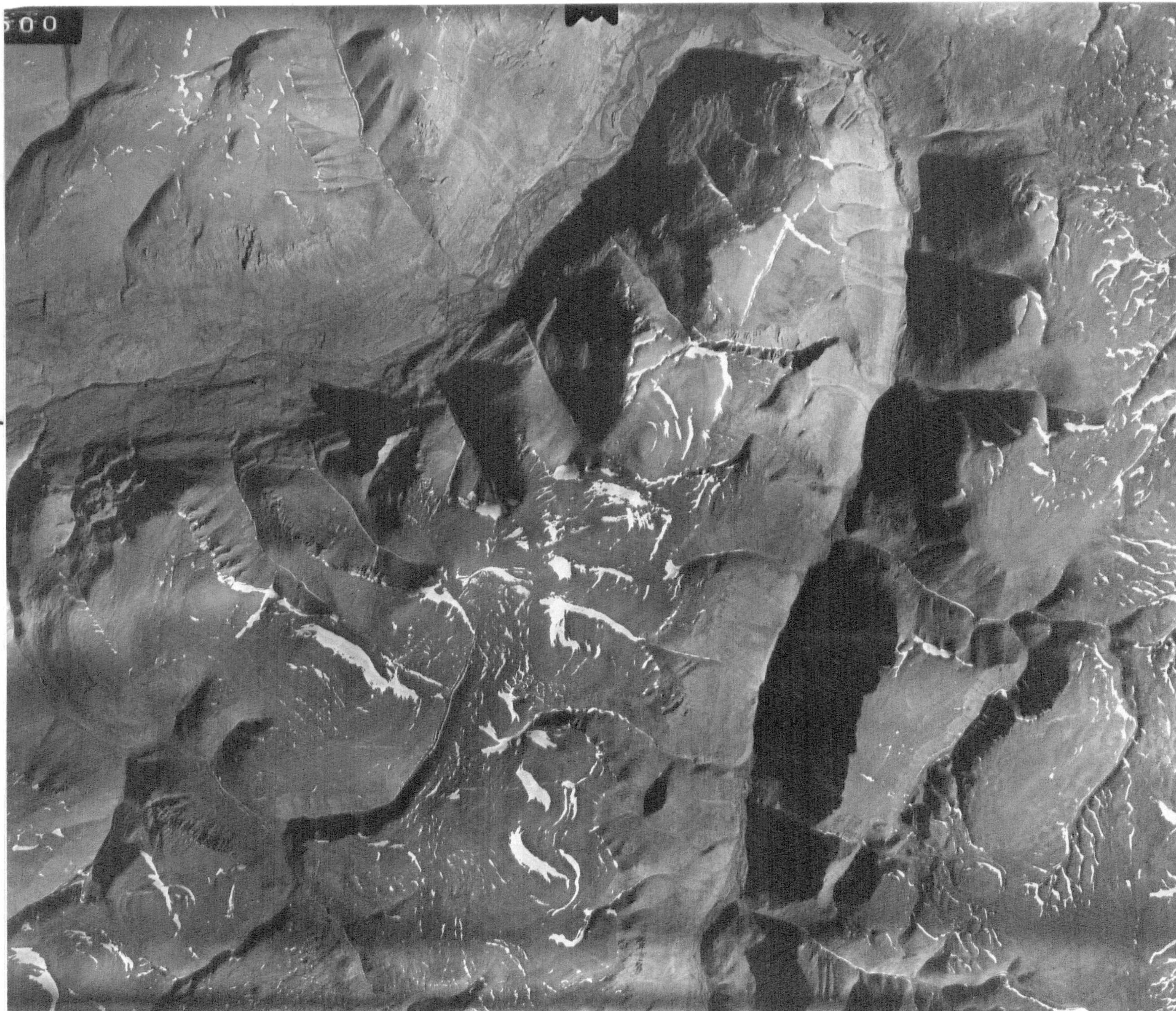


Fig. 3.6
Independence Fjord
Børglum Elv
Børglum River Formation
1
Brønlund Fjord Group
Wandel Valley Formation
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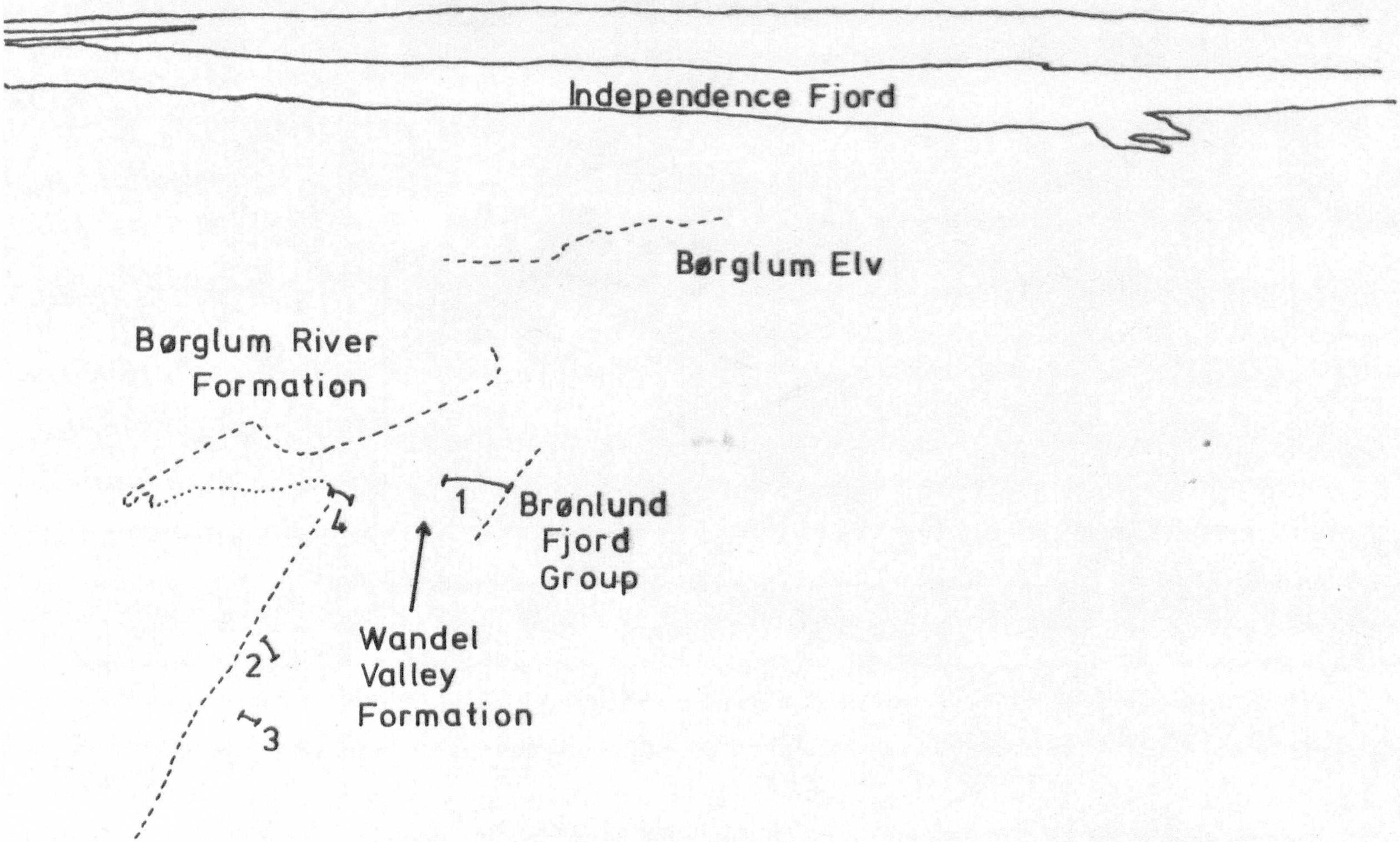
Fig. 3.6



Independence Fjord
Børglum Elv
Børglum River
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Brønlund
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Group
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Wandel
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Fig. 3.7

Fig. 3.7

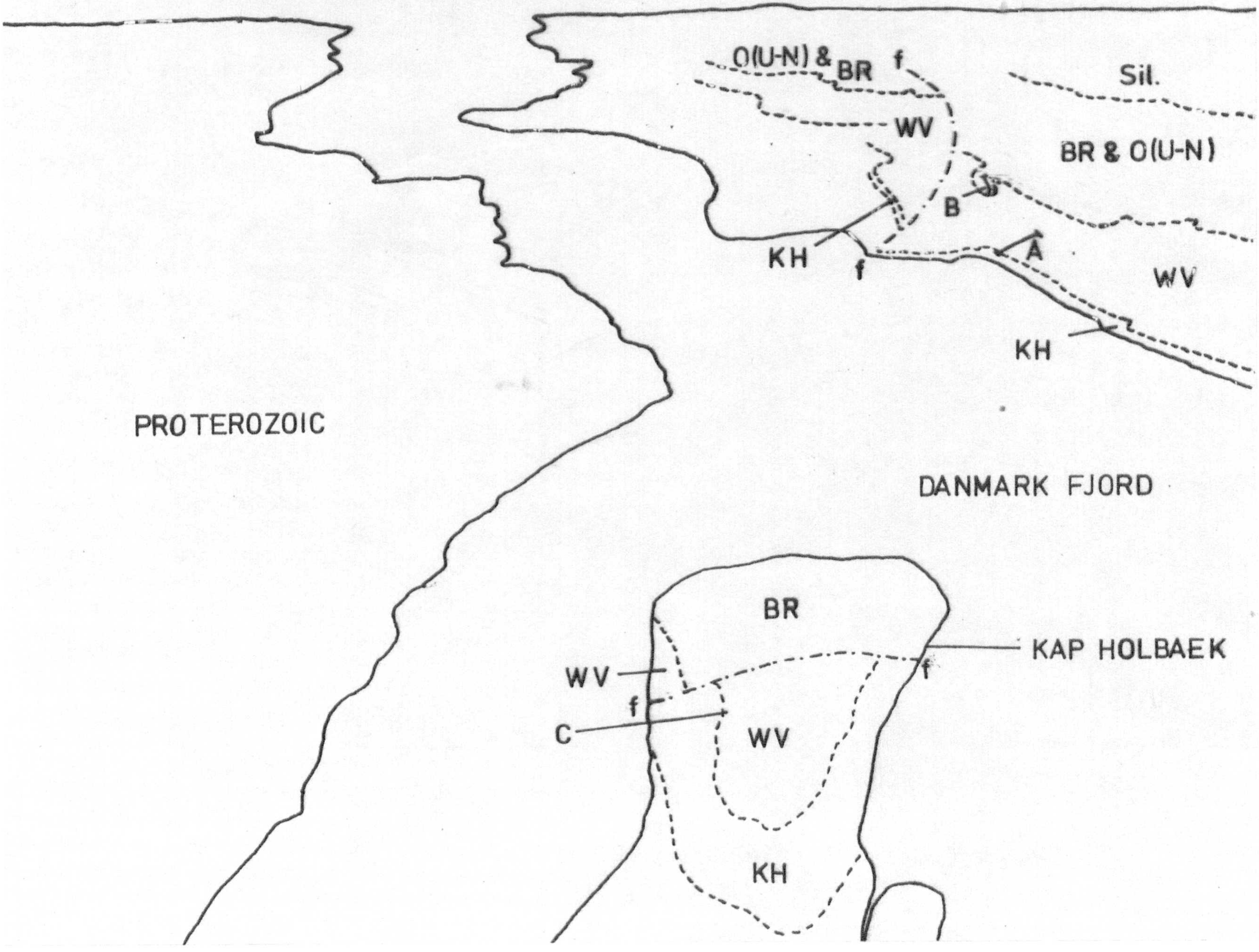
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Fig. 3.11

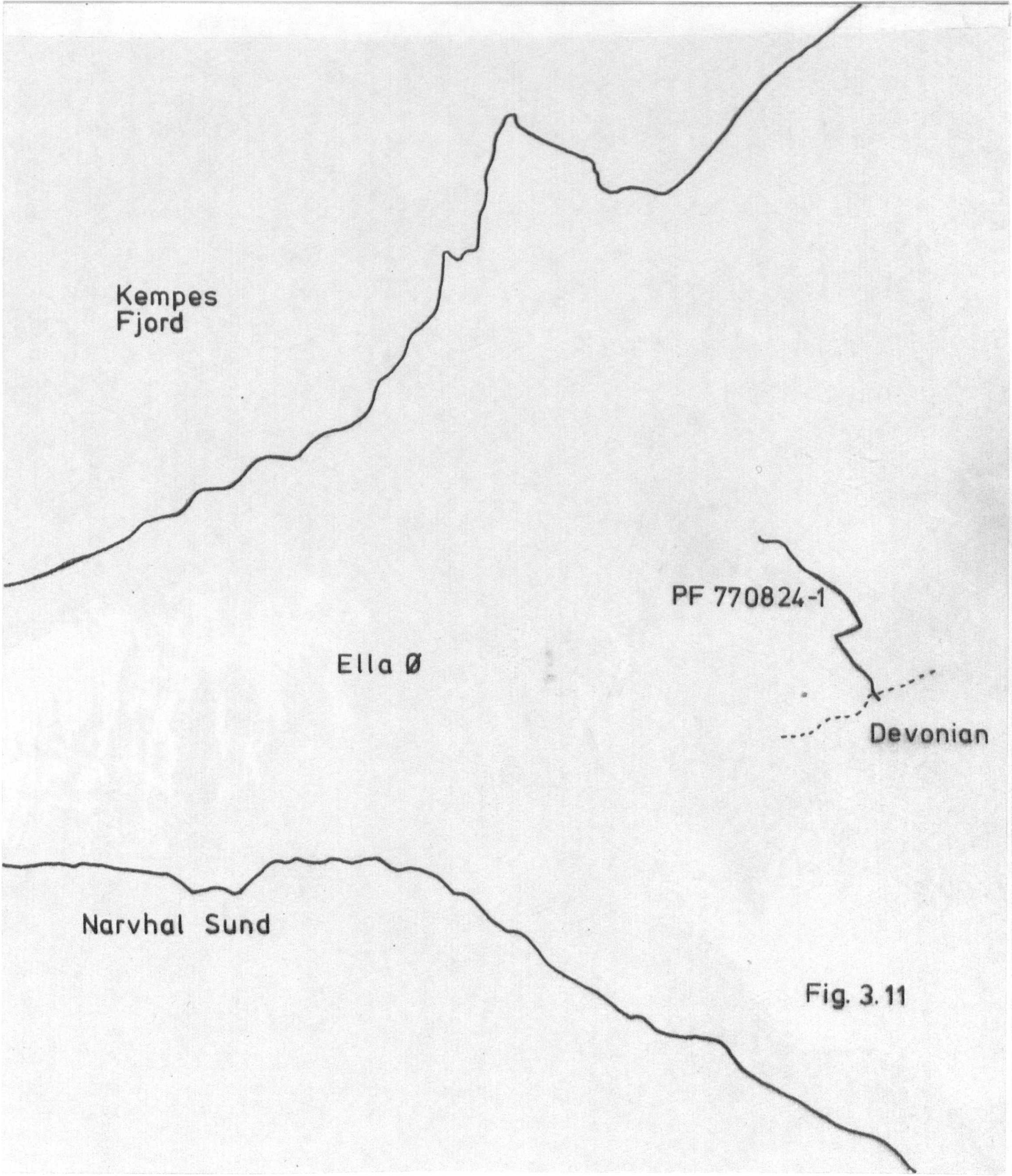
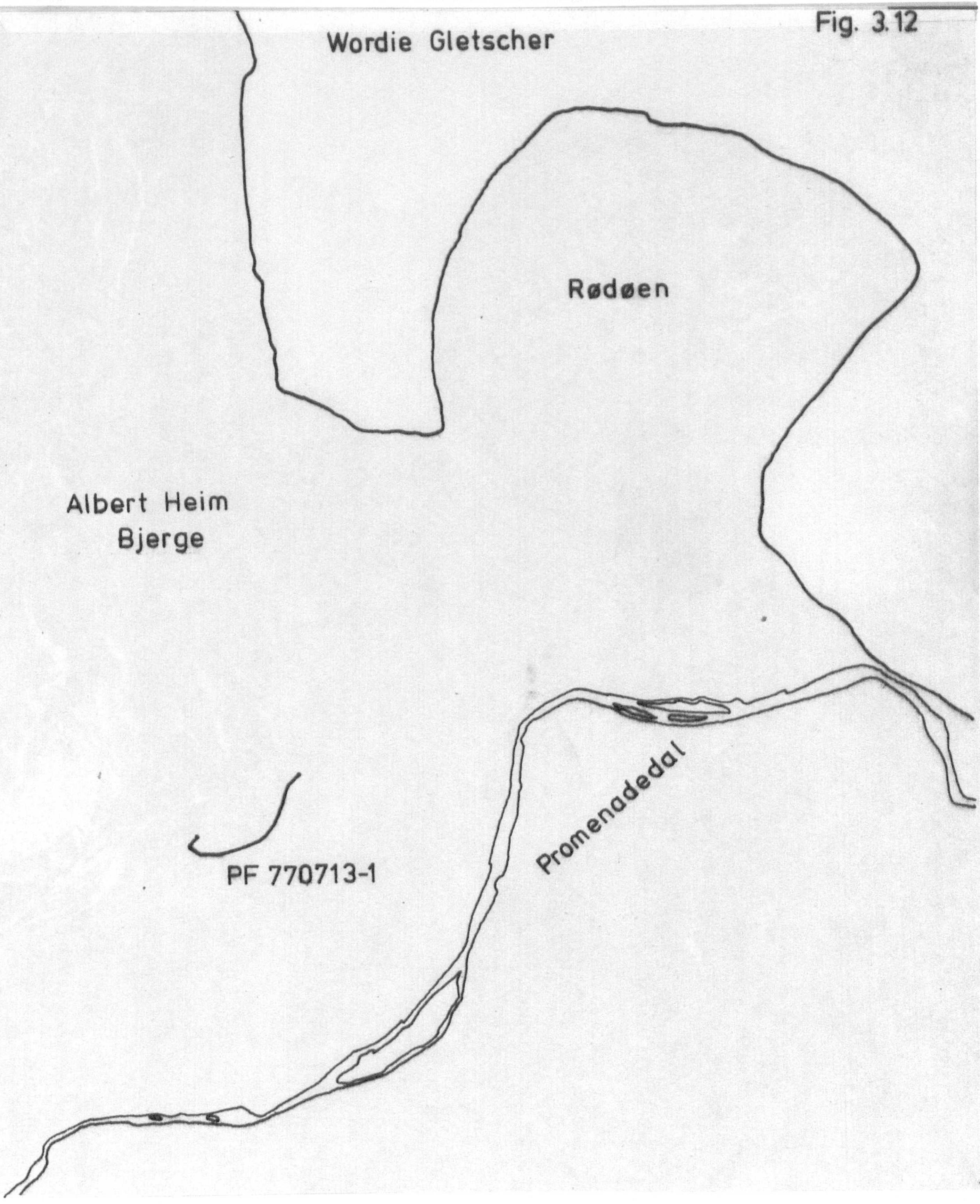


Fig. 3.11

Fig. 3.

Fig. 3.12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